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John McAnulty

**Concept development in relation to the
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A Vygotskyan perspective.**

Doctor of Education (EdD)

31st March 2003

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Abstract

Concept development in relation to the biology of reproduction in secondary science:

a Vygotskyan perspective.

Doctor of Education (EdD)

J McAnulty

The study of concept development in biology comes from a professional concern that arose in my classroom teaching – an inability, after many years practice of the techniques of ‘discovery science’, to accept the theoretical base of the individual secondary school pupil constructing science concepts mainly through experiment.

From this concern arose my research question – the extent to which a developmental space could be defined in which the development of science concepts could take place. The instance for examining such a space would be science concepts of reproduction.

To develop a model for such a space I looked at the work of Jean Piaget, Lev Vygotsky and a number of other theorists concerned with the issue of innate learning mechanisms and of constructivism and social constructivism. I adopted Vygotsky’s dialectical materialist approach in assessing the concepts involved.

To test the emerging model I decided on a case study approach, defined in terms of both the case as instance and the case as issue – instance in that the focus would be a year 8 (Britain year 7) science class, with interviews

across the year group The study would involve the case as issue in that I intended to walk through the process of concept formation in plant and human reproduction with the pupils. I applied a mixture of semi-structured interview and classroom observation, linked through the development of 'structured situations' in which models and materials were made available in specific social settings in the expectation that the pupils would construct meaning.

The outcome of the investigation did not support the initial model, but it did suggest in outline a new model of a developmental space. This suggested that the different goals of teacher and pupils expressed themselves as implicit and explicit elements of the situation, often resolved by the pupils completing tasks without thought. This indicated that a common outcome of schooling was 'encapsulation', formal mental constructs lacking meaning. Elements of a new model would be the role of emotion and of the goal of activity.

and others who have given me the support and encouragement to pursue my research. I am particularly grateful to my supervisor, Dr. [Name], for his guidance and advice throughout the project. I also thank the staff and pupils of St. Fergus for their hospitality and for making me feel at home during my time there. Finally, I thank my family and friends for their love and support.

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staff and pupil's at St.
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Chapter 1

Introduction: A Professional crisis

This research paper is unusual in having a unique historical moment – a ‘critical incident’. That moment was in a school science laboratory on a sunny afternoon in the spring of 1995. I was standing in the middle of a group of year 8 pupils (In Britain, year 7) carrying on a running commentary as I applied a rough-and ready dissection to a typical school daffodil. My notes, recorded immediately after the lesson, record a period of ‘Teacher hesitation – teacher confusion’.

The focus of the lesson was plant reproduction. At the time I was heavily committed to ‘discovery learning’. This approach covered a range of pedagogies, but typically involved open-ended investigations organised by the pupils and following what were presumed to be the authentic investigative methods of science. The pupils were encouraged to interact directly with phenomena, to use informal measuring units and terms and only later link up with a formal science vocabulary. Thus I would encourage children to adopt terms like ‘stringy bit’ or ‘centre bit’ in relation to flower structure before introducing terms like stamen and carpel. Stephen Rowland gives an example of this approach when, in *The enquiring Classroom*, he records a series of experiments by ‘David’, a pupil, to investigate burning (Rowland 1984: 86-92). My demonstration dissection was to be followed by pupil dissections of other daffodils. They were to observe and separate out the main parts of the flower and give the parts informal names made up by

themselves. The lesson would be followed by the teacher introducing the formal vocabulary and then linking the structure of each element to its function as part of a plant reproductive system.

The foundations of pedagogy

Without thinking, I found myself 'hinting' broadly to the pupils about what they might discover. "*You should find four bits – I mean five different bits – no you could find more – no lets say five...*". As I spoke I was aware of a number of discoveries. Firstly I saw that there were a lot of parts, many identical. Then that there were still more than five different parts, then that in fact the flower was a unitary whole that did not naturally split into parts. Finally I realised that what I was asking the pupils to do was impossible. I was asking them to 'discover' elements that were in fact cultural constructs. The divisions and categories were not 'out there' in nature and in the flower but within the individual, their culture and society.

This represented something of a professional crisis. An implicit ontology which had been the foundation for my teaching perspectives had proved false. At the same time that I had been thrown into confusion by this question I had also had to confront the new common curriculum and it seemed to me that the new curriculum also challenged a perspective of active learning from a very different direction, with the elements of science process overbalanced by a heavy factual content. I also felt a more general political concern. It seemed to me that there was a widespread dismissal of active learning and also of the concerns often associated with it of tailoring education to individual development and that what was being offered in its place was quite regressive – both in its espousal of transmission teaching and in an implicit view of the purpose of education as primarily serving the economy and the needs of employers.

Of course these reflections and concerns of mine had not arisen from nowhere. They were part of my development as an extended professional, defined by Lawrence Stenhouse as a teacher able to undertake autonomous

self-development through self-study, study of the work of other teachers and the testing of ideas through classroom research (Stenhouse, 1975: 146) and in fact the specific study had arisen in the course of work for an MA in Curriculum and Assessment with the Open University. I was therefore able to use the resources of the course to examine the theoretical foundations of my pedagogy and to seek for alternatives.

Piaget and Vygotsky

It quickly became clear to me that the theories of Jean Piaget were a major element in the conception of active science in the active science curriculum. As explained by Wood, Piaget laid great stress on the individual, often lone, learner, and their interaction with nature (Wood, 1989: 21). Valerie Walkerdine had shown that Piaget did not have a theory of pedagogy but that his theories had been co-opted to dominate the processes, records, training and even the physical structure of primary education (Walkerdine, 1989: 195). Piagetian theory had less influence in the secondary schools, but Piaget was clearly the inspiration for active learning, with its focus on a developmental process, the learner as individual interacting with nature and the teacher acting as a facilitator. I will have much more to say about Piaget's theories later, as they act as a starting point for my own reflections on teaching and learning.

I began to look for alternatives to the Piagetian approach and eventually came upon the work of Lev Vygotsky.

Vygotsky's suggestion that what was manipulated was signs and that thought and language had a common origin seemed to coincide with my own intuition. James Britton explains that, in contrast to Piaget, Vygotsky stressed the learner in a social setting, interacting with others as she learnt (Britton, 1989: 212). Again, I saw this idea as being fundamental to building a new model of teaching and learning and I will return to this concept of the social learner in more detail later in the thesis. Problems arose because of the unfinished nature of the theory. One of the most well-known and

developed aspects of his work, the zone of proximal development (ZPD) seemed limited in use in the classroom. It clearly had great power in the tutor-pupil relationship, where it could be used to assess the educability of an individual and devise appropriate teaching strategies, but seemed to be more difficult to apply in the classroom to a broad range of pupils with different abilities. One of the ideas to arise from it – of strategies or aids that could act as scaffolding – seemed to me to suffer from a vagueness of definition. On the one hand almost any teaching strategy or aid could be described as scaffolding. On the other hand a specific element of the teaching-learning situation could only be legitimately defined as scaffolding if it fell within the ZPD of specific pupils.

From these starting points arose my research question, which will gain in detail and in meaning when I link it to the methodology that I later decided to employ.

Research Question

To what extent is it possible to define a developmental space based on Vygotsky's theory that charts the learner's movement, during classroom instruction, from initial perception and introduction of technical vocabulary as empty concepts to the internal development of fully formed concepts?

In the main body of the thesis I intend to chart a path through the existing literature, examining the strengths and weaknesses of Piaget's theory, the extent to which Vygotsky's work can be seen as an alternative paradigm or as a complementary perspective, the importance of other aspects of cognition such as language acquisition and computational theories of mind and the direction taken by theories of social cognition since Vygotsky.

A consideration of these general theories of cognition will lead me to a consideration of the process of concept formation in science and the construction of a model of a developmental zone for this process.

A developmental zone seemed to offer the potential for a more specific yet more broadly based model of learning. We would expect to see broad generalities in the way most people learn and from that model develop teaching aids that would be of use to a broad range of pupils. It was quite clear that I did not have the resources nor even as yet the theoretical foundation with which to investigate the whole area of cognitive theory. A useful approach seemed to be to simplify the issues into a relatively trivial case. I use the word trivial here in the mathematical or scientific sense – a situation in which all the elements possible have been removed in order to leave, as far as possible, only the central elements and their relationships. I decided to look specifically at the mechanism of concept formation in the area of plant reproduction. I had the advantage of an earlier investigation and the topic itself allowed for direct manipulation and perception as well as an extensive technical vocabulary and hidden scientific concepts that would have to be made explicit.

A model of concept formation

The starting point for the investigation was the initial model of the process of concept formation. The early stages of perception and manipulation were seen as largely automatic. The sign – in this case the technical vocabulary – is seen as initially being an “empty concept” serving a denotative role in pointing to various elements of the flower. The final stage is when the connotative aspects of the concept predominate and it links up to models, theories and philosophies in the process of formation or already held in a process of assimilation and retention.

The narrowing in of the theoretical aspects of the study will be mirrored by a narrowing in of the methodology. A case study approach seems to allow for the intensity of focus on the individual and on the individual in the small group that will reveal what a Vygotskian approach would expect to be initially a private, internal and ideosyncratic affair. A model of developmental space forces consideration of movement from ‘outside’ to

‘inside’, from word and action to thought and from the individual to the social. This brings into sharp focus the crisis of psychology – that is the dichotomy between the study of behaviour and the discovery of meaning.

“Opportunity sampling” suggested a focus on classroom activity, with a case study methodology that allowed movement back and forth from behaviour to meaning by structuring the classroom activities, providing work materials and moving from individual interview to the classroom and back again.

In reflecting on the literature and the findings of the study I hope to establish the extent to which a theory of developmental space aids understanding of concept formation and also the extent to which the perspective I am suggesting would aid classroom practice and the development of teaching aids that would act as scaffolding in the teaching and learning of science.

Chapter 2

Literature Review: A paradigm shift

Introduction

In chapter two I intend to organise my initial review of the literature around an initial assessment of the linkage between theory and practice. I will argue that such a linkage is possible, but that psychology is unable to act as a foundationist theory for pedagogy because of the ‘crisis of psychology’ – the inability of the subject to resolve the contradiction between a science of behaviour and one of agency and meaning. I will initially approach this problem by treating the broad schools within psychology as paradigms, as in the theories of Thomas Kuhn, each new school produced by the accumulation of contradiction in what went before. In somewhat more depth I will examine the theories of Piaget, of computational models of consciousness linked to language structure and finally the work of L S Vygotsky. The issue put forward will be the extent to which Vygotsky’s work serves as the basis of a new paradigm or, alternatively becomes one element in a broader, social constructivist, paradigm. I will suggest that an understanding of dialectical materialism would lead to a broader acceptance of Vygotsky’s work and narrow down my own study to the process of concept formation in the classroom.

Theory and practice

A great deal of my thesis rests on the assumption of the connection between a theory of psychology, educational theory and educational practice, so it is worthwhile examining the basis of such a connection. P.H. Hirst argues, with some justification, that the basis of educational theory is educational practice. For Hirst, too much of the actual activity of education is contextual and local to a given situation. It draws too heavily on implicit understandings of the practitioners to be subject to the determinist rationalism of the scientific method. At best we can draw upon the sciences, alongside our own experience, to reflect upon and modify our professional understanding and practice (Hirst, 1993:151).

This view seems to me to contain insights about the way in which much professional discourse takes place, but to be too conservative and inward looking a view to explain changes in educational perspectives. We seem to need the insight of other disciplines, above all the insight provided by a theory of mind, to shape our view of the educational process.

A good example of the influence of a theory of mind on practice is given by Valerie Walkerdine. Her account of a primary school teacher coping with a child's mathematical development shows how powerfully Piaget's theory of development structures interpretation of the situation. The teacher being observed appeared unable to view the situation outside of the schema derived from Piaget and definitions of pupil development and the role of the teacher arising from that. Walkerdine observes that the influence of 'child-centred' pedagogy even determined the layout of classrooms and the structure of records. (Walkerdine, 1989: 203).

Martin Hammersley argues that the direct application of educational theory to practice is problematic because the fact that something is seen as a

research problem is no indication that a solution will be found. However research is justified because, although there are difficulties in linking the peculiarities of the individual teacher's situation to research, teachers are not the only audience for research findings (Hammersley, 1993: 216).

Elsewhere Hammersley and Scarth suggest that the role of research is often seen as being to inform policy-makers, although not always to good or progressive effect (Hammersley and Scarth, 1993: 216).

I would accept Walkerdine's view that there is a complex political process that links theory to practice and that the amount of structure that a theory can offer, the procedures that it engenders, can aid its absorption into educational practice (Walkerdine 1989: 200).

My own view is that there is a dialectical process at work between theory and educational practice, mediated by politics. At one pole new insights can help change political and educational directions. At the other pole politics and educational practice can largely determine the direction of research and to some extent what is regarded as an acceptable outcome. The major role of research can be best seen as holistic, setting and amending the discourse through which educational change occurs.

The crisis of Psychology

There is however one major stumbling block to the adoption of a "foundationist" theory on which to base educational discourse. That is the ability of psychology as a science to offer a coherent account of human action – the crisis of psychology referred to by Vygotsky that still exists today. The crisis in psychology is ably described by John Shotter. Is the human an object and the subject of psychology behaviour? If this is so then a reductionist materialism borrowed from the natural sciences will in principle provide a complete description of human activity (Shotter, 1975: 15-20). If the human is actor and the subject of psychology is meaning then psychology becomes a moral science concerned in part with what we should do rather than what we do and the methods of natural science lend a false

authority but little insight (ibid). Although Shotter plumps for a moral science concerned with meaning, the crisis in psychology today, as in Vygotsky's time, consists of the inability of either approach to provide a complete description of human activity.

I found it a useful heuristic device to look at the development of psychology from the viewpoint of Thomas Kuhn. Kuhn saw science as developing through a series of "paradigm shifts". Within a paradigm a dominant model was used to explain phenomena and anomalous results were ignored or explained away. Eventually the accumulation of anomalous results led to a paradigm crisis, the collapse of the dominant model and a "scientific revolution" leading to the adoption of a new paradigm (Kuhn, 1970: 10-18).

Vygotsky commented on a dominant school of Gestalt psychology that relied on introspection to observe processes of thinking. He saw this as a form of idealism (Vygotsky, 1971: 2). Eventually evidence accumulated that there was little in the way of a common description to be found in the introspective studies of the Gestalt school and the paradigm shifted to a form of logical positivism called behaviourism developed by Hull and then by BF Skinner (summarised in Wood, 1989: 3).

The Gestalt psychologists understood perception of the outside world to be a holistic process. They relied heavily on subjective introspection as a method for understanding consciousness. (Eysenk and Keane, 2000: 28) They made several important observations about the nature of visual perception, most based on or derived from what Koffa called "The law of Pragnanz" – that of several possible geometric shapes the one actually perceived would be the best, simplest and most stable (Koffa quoted in Eysenk and Keane, 2000: 24). A constant problem was that it was difficult within the subjective view to define what best and simplest was and the danger of a circular argument was always present. The Gestalts made the idealist assumption that perceived objects were mirrored in the brain by electrical fields in the brain,

but the existence of such fields was fairly conclusively disproved by Lashley et al in 1951 when gold foil implanted in the brains of chimpanzees failed to disrupt perception (quoted in Eysenk and Keane, 2000: 26).

The introspective paradigm was largely succeeded by the logical positivism of the behaviourists Hull and Skinner. Hull refused to speculate about mental process, arguing that any theory ought to begin with behaviour in which a stimulus led to a response (quoted in Shotter, 1975: 41). B F Skinner's behaviourism is an example of the effects of theory on educational practice (Wood, 1989:4). It denied a theory of meaning, focusing more on observable inputs and outputs, but it was highly structured and that structure lives on in concepts such as positive and negative reinforcement and in the structured learning programmes, once common in book form and now found in some educational software.

From a Kuhnian perspective the progressive aspect of a behaviourist approach can be seen in the fact that it allowed counter-intuitive findings – for example that partial reinforcement of a stimulus was more effective than continuous reinforcement. Like other theories of psychology it generates an educational literature centring around positive and negative reinforcement and behavioural aspects of teaching and learning such as time on task. At the centre of the behaviourist approach was the idea of an “empty organism” – that we should ignore cognitive processes in favour of a pure stimulus – response model. The paradigm crisis for the behaviourists came when it was demonstrated that test subjects ignored the reward/reinforcement in favour of the problem-solving aspects of the activity. The evidence for an internal cognitive mechanism directing goals, learning and behaviour for the organism was overwhelming. (ibid: 4) A paradigm crisis for behaviourism was followed by a new paradigm of constructivism in which the organism was seen as actively constructing knowledge.

An overview of Piaget's learning theory

Piaget's work retained a link to behaviourism in that the stimulus-response chain was replaced by the scheme, innate structures arising from simple reflexes and responses that evolved into flexible patterns of action. His work is usually presented as a series of stages of qualitative changes in the development of the child.

The stages are:

Sensorimotor

Motor reflexes develop, generalise and become purposeful. The foundations of intelligence are built on action on the environment. (Piaget and Inhelder, 1973: 4). External data undergoes a process of assimilation as it is filtered through existing action schemes. In turn the schemes themselves are modified by a process of accommodation. These processes, which are holistic processes of the organism, evolve from reflex to habit and from habit to purposeful behaviour (ibid: 2-6). An example is suckling. The reflex is innate, but rapidly evolves into a more complex and adapted habit structure. Later the child shows purpose in systematic thumb-sucking (ibid: 7). Action enables the construction of reality, involving the formation of schemes of the permanent object, space, time and causality (ibid: 13-19).

Concrete operational

Initially the child is preoperational. Children acquire representational skills in mental imagery and language but are unable to view the world from perspectives other than their own. As they mature they can take into account more than one perspective simultaneously and can represent transformations as well as static situations (ibid: 96). [In the US pre-operational and concrete operational are taken as separate stages]. Just as the sensorimotor stage involved a decentering at the level of action so the

preoperational stage involves decentering at the level of representation in the social universe of other people (ibid: 95). A long maturation process involves the schemes of space, time etc and development of perception, memory and the semiotic function. The co-ordination of these in action constitutes the stage of concrete operations. Concrete operations involve joining and ordering and central to these is the concept of conservation (ibid: 97). The child is able to carry out operations involving listing and arrays and tasks of class inclusion (ibid: 102-103). The beginnings of causality are present (ibid: 110)

Formal operational

The child develops adult reasoning patterns. A final decentering takes place from the concrete to propositional logic, involving the nonpresent and the future. She can think logically and abstractly and can reason theoretically (ibid: 131). A combinatorial system develops which allows combination and permutation. The child can carry out operations upon operations. Inversion and reciprocation become more abstract and allow the development of the "4-group" of identity, inversion, reciprocation and correlation (ibid: 131). It is from this basis, rather than the concrete, that concepts of proportion and probability develop and allow for formal logic and the experimental approach (ibid: 140).

The pattern of stages is what is usually available to the classroom teacher, but it rests on another series of assumptions that are not always clearly presented. Piaget saw intellectual development as a process of biological maturation which took place through a system of adaptation. Adaptation was accomplished by a mechanism of assimilation [absorbing new information into existing schemes] balanced by accommodation [changing existing schemes to incorporate new observations] (ibid: 5-6). Finally the bedrock of Piaget's investigation was genetic epistemology - the evolution

of knowledge structures. He saw knowledge as arising from action on the world and having an end or goal in the operations of formal logic (ibid: 155).

Critics of Piaget

The Piagetian perspective, with its focus on meaning, seemed to offer a solution to the difficulties faced by the behaviourists. However contradictions accumulated. A theory of biological development did not seem to allow much space for an active pedagogy. There were difficulties in showing the existence of the stages predicted. The preferred methodology of the Geneva school, the experiment/structured interview, was shown by Donaldson not to be an effective tool. The child subject's view of the meaning of the situation was often quite different from that of the experimenter. (Donaldson, 1993: 163-171)

In Kuhnian terms the Piagetian paradigm had supplanted the earlier SR theories. From the Kuhnian perspective we would expect the accumulation of problems and the development of crisis to be the prelude to a new paradigm. In fact aspects of the Piagetian theory have been attacked by researchers supporting a constructivist stance. Initially many of the researchers would have supported Piaget's model of the individual learner interacting with nature and constructing meaning, but contradictions in the theory and in its interaction with nature tended to move them in the direction of a social constructivism where the learner is part of a group and a culture. Donaldson found that context and familiarity influenced the outcome –specifically that small changes in the experimental setup and small changes in verbal cues together produced a large change in the success rate in class inclusion tasks. (ibid: 171). Bruner offers an overall critique of a private, egocentric, unmediated learner and offers an alternative of a culturally situated learner, negotiating with others. He points out how the acquisition of language involves a "diectic shifter" that involves taking

the place of the other and denies the assumption of egocentricism (Bruner, 1989: 38). Bishop indicates that even the domain of Mathematics can only be understood as a cultural construct (Bishop, 1989: 85).

Lunzer's critique is more fundamental. The ideas of logic as the goal of thinking processes or of those processes exhibiting discontinuity are both flawed he suggests (Lunzer, 1989: 27). Strong support for the former critique is offered by Carey, who shows that cognitive conflict does not lead to the abandonment of traditional concepts in favour of scientific ideas (Carey, 1989: 106). Walkerdine points out a contradiction between the constructionist, agentic picture of the learner and the normative, biological constraints of the theory (Walkerdine 1989: 196). She suggests that implementation of Piagetian ideas in an educational setting tends to assume an active construction which is directed by the individual learner, yet the model is based on a biological determinism of maturation and adaptation.

Wood sums up many of these criticisms, but, in an echo of the Kuhnian perspective, points out the difficulty of these ever adding up to a refutation because Piagetian theory per se is based on an internal understanding not visible to the observer and it is impossible to decide if misunderstanding is at the end of the day based on the tyro status of the learner or their ability to carry out class inclusion or decentering (Wood 1989: 83).

The fundamental contradiction of the Piagetian school was the view that the developmental process had a goal and that goal was a system of logic. The assumption here was that meaning was already inherent in the world and that the maturing human discovered the inherent logic. Evidence accumulated that logical thinking was a specialist form of thinking and usually not the routine form and that many adults did not arrive at a use of formal logic as a way of thinking about the world (Lunzer, 1989: 27).

A computational model

As the Piagetian model of cognition faced a paradigm crisis, researchers moved from the difficulties of meaning back towards behaviour. The promise of linking meaning and behaviour was a possibility offered by theories of computation.

In computational theories information about the outside world is converted to data by sense organs. The brain is a modular structure which moves, stores and processes the data to produce an appropriate output. Key elements of the theory dealt with perception, memory and planning (Eysenck and Keane, 2000: 2). As with other new directions in psychology, there was a surge of progress with many elements of new research. Lines and edges were seen as the starting point in computational processes which built perception. The magic number five, plus or minus two, seemed to show the limits of a central processor (Miller, 1956: 91). There were however problems. The area split early on into cognitive science, concerned with artificial intelligence and designing computers that could model processes such as speech recognition, translation and visual perception, and cognitive psychology, concerned with identifying computational structures and processes in the brain.

This division did lead to many useful insights, but it also led to paradigm crisis. Success achieved with computers tended to stress the difference between them and minds. Massive problems were posed by the digital and sequential nature of computer processing. Attempts were made to build parallel processors but fundamental differences with mind remained.

Neurones are not digital, nor are they linked in a linear sequence. Each neurone has multiple connections and the signals are chemical and analogue in nature. The neural structures and substructures are not linked by any logical structure and structures of the brain are adaptationist at a number of levels (Dennett, 1991: 112). Each population of neurones undergoes a process of developmental adaptation and also an adaptive process during

processes of perception and memory (ibid: 184-186). There is evidence for a process of evolutionary adaptation during which brain structure was formed (Mithin, 1996: 205-211). A body of evidence also exists for limited compensatory adaptation when some brain structures fail during stroke and other brain structures adapt to restore function (Sacks, 1986: 12-18). In any case, even if one could trace a direct sequence from the individual neurones to concept formation, it would be difficult to argue that one caused the other. A strict biological reductionism seems unable to find a ghost in the machine.

Daniel Dennett makes explicit the basis of many commonsense ideas of mind – the ‘Cartesian theatre’ where an observer sits inside the brain and directs it. This does not explain consciousness, but merely defers such an explanation indefinitely at the cost of a dualist welding of matter and spirit to make mind. Dennett’s solution is to propose ‘multiple drafts’ of external reality that compete with one another (Dennett, 1991: 111-113). Stephen Mithin draws upon evidence from anthropology to argue that the environment may have acted over evolutionary time scales to select various internal mental structures to act as ‘modular intelligences’ such as social intelligence, technical intelligence and a natural history intelligence. These intelligences are presumed to be present to some extent in other species in an isolated, unselfconscious form, but are linked and transformed in humans by language, which links the modules into a unity (Mithin, 1996: 64-71).

Bredo argues that mental processes are fundamentally different from both computers and from the logical and academic world of researchers. Mental processes occur within a holistic world of thought and action and even in principle we cannot expect computational processes to explain thought (Bredo, 1999: 28).

Stephen Pinker has made an ambitious attempt to unite the computational model of the mind with theories of biological determinism and evolutionary determinism, using a theory of language as the cement joining the elements together. He argues that a computational model of the brain is fundamental

and basic - akin to the cell theory in general biology (Pinker, 1998: 83). He also asserts that much of our behaviour is determined by evolution and genetics, having been selected for by environmental pressure in paelolithic times (ibid). Stephen Rose attacks this sort of determinism as just so stories. He compares them to Kipling's story of how the elephant got its trunk - essentially as fiction and speculation involving a form of circular reasoning (Rose, 1997: 234).

Pinker draws heavily on the recursive and combinatorial aspects of language that make it capable of literally infinite modes of expression. He accepts Chomsky's argument that the speed with which children acquire language is evidence for a LAD – language acquisition device – which is hard wired into the brain. He also draws upon the evidence of grammar. There are only a relatively limited number of grammatical rules and, while these differ between languages they are consistent within each language. This is seen as evidence for pre-existing brain structures for producing and interpreting language. The fact that children often make consistent grammatical mistakes, such as applying the regular past tense by, for example, saying *losted* rather than *lost* is seen as further evidence for this thesis. Pinker supports Chomsky's assertion of a deep structure to language. Sentences seem to structure together as if the brain expects noun or verb phrases and can only assemble them in certain ways. Certain random collections of words seem accepted by subjects as appearing to be grammatical while others are not (Pinker, 1998: 118).

It appears to me that a general weakness of theories of evolutionary determinism is that they assume a logic to evolution that is not inherent to the process. Stephen Jay Gould points out that evolution allows for survival of the fit and not, as many assume, survival of the fittest. He also points out that adaptive structures have a dual and contingent nature, allowed to change to carry out more than one function (Gould, 1993: 118).

If the brain were in essence a computer then we could consider the crisis of psychology to have been essentially solved, and we could look to a deeper

and deeper understanding of computation and of the structure of language. Unfortunately computational theory seems to assume the identity that it later proves. Evidence that computers can appear to mimic some of the processes of perception or can produce outcomes similar to a human operator (the Turing test) do not show the identity claimed. A closer examination of mental processes does show the processing of data, but it is in a holistic, adaptationist and dialectical way very different from that of computers. Key to understanding here seems to be the process of movement, both upwards and downwards, outwards and inwards (Eysenck and Keane, 2000: 54).

The paradigm offered by Piaget was beset by contradiction. Computational theory had appeared to offer a solution to these contradictions but, although it offered many fresh insights, it did not offer a fully convincing overview of cognitive development. A theory of cognition should allow both for culture as well as for computation, and this is what LS Vygotsky set out to do.

An outline of Vygotsky's theory

An alternative paradigm that asserts a constructivist perspective while avoiding the accumulating difficulties of the Piagetian theory has been outlined by L. S. Vygotsky. Vygotsky [and Marx and Engels before him] would refute Pinker's reductionism in principle. Culture cannot be explained by biology. Theorists trying to understand human thought frequently look to childhood development and also to the evolution of the human species and its links to other primates. For Piaget the main theme of such perspectives was their continuity. Human problem-solving involved the innate intelligence shown by other animals in a quantitatively amplified form, amplified further and released from the restrictions of the immediate situation by the semiotic functions, including language.

For Vygotsky the shift from animal to human and from child to adult involved discontinuities and qualitative change. In *Thought and Language* he outlines the distinction between animal and human as follows:

1. Thought and speech have different genetic roots.
2. The two functions develop along different lines and independently of each other.
3. There is no clear-cut and constant correlation between them. The apes display an intellect somewhat like humans in certain respects (the embryonic use of tools) and a language which develops differently.
4. The close correlation between thought and speech characteristic of man is totally absent in the apes.
5. In the phylogeny of thought and speech a prelinguistic phase in the development of thought and a preintellectual phase in the development of speech are clearly discernible.

Applied to early childhood his conclusions became:

1. In their development, thought and speech have different roots.
2. In the speech development of the child, we can with certainty establish a preintellectual stage, and in his thought development, a prelinguistic phase.
3. Up to a certain point in time, the two follow different lines, independently of each other.
4. At a certain point these lines meet, whereupon thought becomes verbal and speech rational. (Vygotsky, 1971, p 44)

So Vygotsky agrees with Piaget in seeing early intelligence in the child as not qualitatively different from the intelligence of animals and primates. However he sees the development of speech as marking not a quantitative amplification but a qualitative difference. This is not immediately apparent because much early speech is pre-intellectual - many words such as "because", "if", "when" are clearly used without understanding. Thought and speech intersect because speech immediately begins to serve a

mediational role. The child is operating with culturally acquired signs and therefore at a level of abstraction from reality not available to other primates.

This mediational role of language allows Vygotsky to define the unit of verbal thought as word meaning. (Ibid:120). Word meaning is a dynamic rather than a static process.

“Thought is not merely expressed in words, it comes into existence through them” (Ibid: 125).

Vygotsky does not mean that all thought is verbal. Rather verbal thought is a uniquely human activity. Verbal thought acts as a mediator. The level of symbolic abstraction involved in the use of words creates mental structures that no longer intersect directly with perception of reality but with symbols that, by their very existence, involve a grouping and classification of the world. “Bow-wow” can be applied to a whole range of objects by the young child, but it eventually comes to mean dog in a complex interaction with others that enables the selection of salient features, classification and grouping so that a distinct group of dogs becomes defined and denoted by one symbol. This enables children to move mentally in space and time and thus plan activities and collaborate with others.

The vocal and semantic aspects of speech move in opposite directions - outwards from the whole to the particular and inward from the particular to the whole (ibid:126).

Both Vygotsky and Piaget observed solitary speech in the child. Piaget labelled it egocentric and saw it as linked to the child’s inability to take the viewpoint of others. Vygotsky observed it as having a number of functions in problem solving, beginning as descriptive and going on to serve a more advanced mediational function in planning and directing activity. When this speech was disrupted problem solving did not take place. He argued that the external development of speech towards a more formal communication

instrument was mirrored by a hidden development of idiosyncratic internal thought. Egocentric speech in the child moves outwards and becomes more formal to become social speech. It moves inward, becoming more informal and idiosyncratic, to become verbal thought. This process was generalised to outline a spiral of development of higher mental functions where each stage was first apparent externally and controlled and mediated by external signs and then developed internally to become mental processes and structures (Vygotsky, 1978: 36).

School occupies a special place because the knowledge there is “scientific” – formal and non-spontaneous. (ibid: 89) The child can more easily carry out logical reasoning because she knows that she knows the information. She knows many other things from everyday life as spontaneous concepts, but the fact that she knows about them may not be available to her. School can offer a ‘scaffolding’ – the teacher lending consciousness to the child of concepts not yet fully developed.

Within school knowledge writing and literacy have a special place. (ibid: 109) They allow a further abstraction on which rests a greater appreciation of social others and a greater formalisation and structuring of ideas. The child has greater freedom to move in time, away from the immediacy of the spoken word. Writing develops from the fusion of speech and gesture through drawing. It is initially a second order of symbolisation - representing speech – but a complex internal development leads to it directly representing concepts (ibid: 115). One of the many concepts thrown up by Vygotsky was that of the ‘Zone of Proximal development’. It can be understood as the difference between the assisted and unassisted performance of the learner and is arrived at by testing a child’s understanding when they were working alone and then testing again with adult help. The amount of help that would benefit the child was called the Zone of Proximal development. For example a child that was awarded an age score of eight alone and an age score of eleven when helped was said to

have a ZPD of 3. The ZPD indicated the developing 'buds' of new skills, while normal testing simply recorded what the child could already achieve. Put simply, the ZPD indicated the educability of the child at that point in time (ibid: 85-87).

Vygotsky put great stress on science teaching in schools. He appears to have meant two things by this. Partly the formal discipline of science itself and more generally all teaching and learning in schools in the sense that it is formal and abstract in contrast to spontaneous everyday knowledge.

Like Piaget's hypothesis, Vygotsky's theory can be dealt with at a number of levels,

1. As an account of cognitive development
2. As an outline of the mechanisms of such development
3. As an ontological and epistemological statement - in this case of dialectical materialism.

Chalmers explains dialectical materialism by quoting Marx:

"It is not the consciousness of men that determines their social being, but, on the contrary, their social being that determines consciousness." (Chalmers, 1980: 136).

In fact by itself this would simply be a statement of materialism. Marx specifically adopted the idea of a dialectical process in which consciousness could reflect back on being because of his opposition to any mechanical and reductionist materialism.

In the Kuhnian view of scientific revolution a new paradigm does not so much replace an existing paradigm as subsume it. It explains phenomena also explained by the preceding paradigm, incorporates aspects of the

preceding worldview and explains new phenomena. An example would be the fact that Piaget's theory did not invalidate ideas on reinforcement introduced by Skinner.

From this viewpoint it cannot be said that a Vygotskian paradigm has been developed which supplants and incorporates earlier paradigms. There are a number of reasons why this is so:

- Vygotsky's theory is incomplete.
- It is unclear if the theory should be developed in a strong form, as an overarching theory of psychology, or in a weak form as part of a more general paradigm of social constructivism.
- The theory could be developed separately from Vygotsky's more general views, especially his support for dialectical materialism or it could be seen as closely bound to a more general Marxist viewpoint.

More recent research, such as work by Lave and Wenger, appears to raise questions that arise from a Vygotskian perspective but have not been closely bound to it. This includes work that appears to move consciousness "further out" away from the individual and into the group and cultural and other work that questions the formalism and abstraction of school both as a method and as a goal of learning (Lave and Wenger, 1999: 22).

The most pressing difficulties lie in relation to Piaget's theory. Does a Vygotskian perspective supplant Piaget? Do they exist separately, explaining different things? Do they complement each other, exploring different facets of the same reality?

The issue here is the extent to which critiques of Piaget would lead simply to a broadening of the context of development to make it more social or if they indicate a collapse of the paradigm. The first conclusion would lead to

a “weak” social constructivism in which Vygotsky’s perspective is simply one of many competing tendencies and it would be mistaken to speak of a distinct ‘Vygotskian’ cognitive theory. The second would be strong justification for the investigation of Vygotskian theory to establish its overall plausibility as a general theory of cognitive development.

Is Vygotsky’s theory a global alternative to Piaget’s learning theory and to a broad church of social constructivism or is it a contribution to that broad church, one perspective amongst many? Precisely this division occurs between Jerome Bruner, introducing ‘*Thought and Language*’ and Michael Cole and Sylvia Scribner, introducing ‘*Mind in Society*’.

Bruner explicitly detaches Vygotsky’s research from his Marxist background: He argues that there is little point in tracing the ideological course of Vygotsky’s work (Vygotsky, 1971 intro: V) and that Vygotsky was an original, not to be understood in terms of Soviet concepts (ibid: VI).

“He transcends, as a theorist of the nature of man, the ideological rifts that divide our world”. (ibid: X)

So Bruner’s critique of Piaget and endorsement of Vygotsky lead, not to a general Vygotskian theory, but to a social constructivism that incorporates both and links them to a range of other theories. This work involved an information-processing approach which would have been at odds with Vygotsky – specifically breaking with his idea that the verbal thought was the basis for analysis. Bruner now says that information-processing models, while informative, are “incommensurable” with a cultural cognitive approach (Bruner, 1997: 6).

Bruner tends to focus on the contextual aspect of teaching and learning. This is a valuable approach, but falls into the strong empirical tradition in the US and militates against any over-arching theory. Thus in chapter 1 of *The Culture of Education* he lists 9 broad areas that impinge on learning from perspectival (ibid: 13) to narrative effect (ibid: 39). He lists 4 ‘folk

pedagogies', one of which – pupils as thinkers – again subdivides into another 4 groups (ibid: 50).

These broad areas are:

“parts of a broad continent, their significance to be understood in the light of their partialness” (ibid: 65).

Bruner clarifies his position by taking each area and indicating a mechanism through which they operate in the culture of education and how they may be studied or become the subject of policy. So the perspectival element is explained as the tension between individual and culture and the area of study is education as both agent of change and force for conservation. Later interaction is said to have as its mechanism intersubjectivity and understanding the mind of others, its focus scaffolding and mutual learning. Finally narrative is based on the dominance of the logico-scientific over narrative and the focus of study the balance between the two within school.

Bruner makes a clear point in each area. I am forced to agree that learning really is as complex as he presents it. On the other hand not all the areas can be of equal significance. Should we not make a selection? Is not part of research a necessary reduction and simplification of the problem?

Bruner sees education as being plagued by insoluble “antinomies” and endorses what appears as a post-modernist model of narrative and integration (ibid: 91). Antinomies by their nature are permanent features of analysis, for example, the tension between individual and culture. Vygotsky would have seen these as contradictions whose solution lay in struggle and movement and eventual resolution through synthesis. Bruner’s cultural relativism makes it easy to incorporate Vygotsky into his educational perspective, but more or less impossible to speak for a distinctive Vygotskian perspective.

A Dialectical Materialist Perspective

In sharp contradiction Michael Cole and Sylvia Scribner, in their introduction to *Mind and Society*, put Vygotsky's ideas within the context of Marxist theory. Where Bruner had looked at, and rejected, the sudden political shifts within a Stalinist bureaucracy, they looked to the longer history of classical Marxist theory (Vygotsky, 1978: 6).

They argue that Vygotsky saw the methods and principles of dialectical materialism as a solution to key scientific paradoxes facing his contemporaries (ibid: 8). It was in fact a central claim of classical Marxism that it provided an approach that superseded the approaches of formal logic and science and provided a more powerful means of interpreting reality.

One introduction to dialectical materialism is provided by EV Ilyenkov (Ilyenkov, 2000). The starting point for Marx's theory was the philosopher Feuerbach (ibid: chapter 8, 3 of 13), who argued that people thought with their brains but only in unity and contact with nature. Marx argued that people did not have direct contact with nature but thought in unity with society and as a result of an historical process.

Vulgar materialists saw the ideal as a physical structure inside the brain. Marx argued that the ideal existed only as an image of activity. That activity was social activity situated in history. Humans only interacted with nature through their social being.

From this point of view the ideal is simply this objective being of the object and a dialectical materialist view of consciousness is simply the movement back and forward from material to ideal and back to material, mediated by the social reality of human existence.

An example of this process is the approach to value in economics. Ricardo defined value as equal to labour but also defined profit as value (ibid: chapter 10, 2 of 10). This led to a contradiction which was resolved when

Ricardo's followers abandoned the labour theory, but the price of this was that value in classical economics is totally subjective. Value is what people think it is.

Marx rejected this but did not resolve the contradiction. He argued that the contradiction was necessary and was in fact built into each object as a contradiction between its value as a commodity and its use value. The contradiction was not resolved but instead acted as a source of movement, leading to the development of money as a medium of exchange, then to money as a commodity and then to financial crises.

The labour theory of value is not widely accepted, but few people are aware that the alternative is to see the massive crises of our world as being driven by an immaterial ideal construction, lacking material reality.

AF Chalmers attempted to apply the method of dialectical materialism to science by arguing that theories about science itself can be divided into 'subjectivist' accounts that focus on the beliefs and sensory impressions of individuals and 'consensus' theory that focuses on a special kind of community, the scientific community. These theories tend to find it difficult to refute charges of relativism, while the subjectivist accounts are charged with a psychologist orientation. Chalmers argues for a third, objectivist theory where science can have a relative autonomy from both the individual scientist and the science community, but only if we adopt a dialectical materialist position and view science as 'process without subject' (Chalmers, 1980: 99-104). A more conventional Marxist approach would be to talk of praxis – the unity of theory and practice. Gavin Kitching praises Marx for attempting to break from 'picturing' accounts of reality, but then accuses Marxism of simply adding dynamism to the picture. Kitching argues that action can refute Marxist praxis because we can 'experience' experiments and their outcome without language (Kitching, 1994: 94-96). I would argue that this begs the question of where the

apparatus and scientific cooperation came to carry out the experiment in the first place and opens up the questions posed by Vygotsky of word/meaning and the use of cultural tools)

Michael Cole and Sylvia Scribner link Vygotsky's theory to Engel's claim that tool use transformed humanity through human transformation of nature (Vygotsky, 1978: 7). Engel's *Dialectics of Nature* was an attempt in practice to prove the Marxist claim of a more powerful analysis of reality. Its analysis of evolution and human cognitive development asserts that people and societies transform themselves and the nature of consciousness through tool use. And they quote from Vygotsky's unpublished journals.

"I want to approach the study of mind having learned the whole of Marx's method" (Vygotsky, 1978: 8)

They present this as evidence that he saw the dialectical method as a scientific tool rather than as an item of official ideology.

Michael Cole later returned to the issues when, with Wertsch, he compared the work of Piaget and Vygotsky and found support for social interaction within Piaget and for individual action within Vygotsky (Cole and Wertsch, 1999: 1) and They identify what they consider to be a core element of Vygotsky's theory with no correspondence in Piaget – the primacy of mediation – and quote Vygotsky;

"The central fact of our psychology is the fact of mediation" (Vygotsky, 1982: 166, quoted in Cole and Wertsch, 1999: 1)

In my view, Vygotsky would have seen very little to argue with in the Piagetian scheme if it were applied to learning in animals. The process of learning here involves action and a direct interaction with nature. He saw human learning as involving the manipulation of sign, but the sign is not created by the learner, it is already present in society. Humans learn in a

much more abstract and generalised way than animals but, more than that, the greater part of learning no longer takes place as a direct interaction with nature. Learning is social and consciousness arises out of society, itself formed by a history of collective interaction between humans and nature. For Cole and Wertsch the higher mental functions are, by definition, culturally mediated, involving indirect action, taking material shaped by prior human production and incorporating it as an aspect of action. Artefacts do not simply facilitate mental processes, but shape and transform them. (ibid: 3).

The simplest approach to mediation is to see the Piagetian scheme repeating itself, but this time manipulating not nature or objects, but manipulating a sign. This immediately means a higher level of abstraction because the sign represents not an object but a class of objects. Not only that, the word is also an empty concept, infinitely malleable and able to build an endless range of structures and linkages.

This means a more complex mental map which does not link object to object or action to action but builds a representation of a rather fuzzy private world where concepts are defined by their relationships. Metacognition becomes possible, as we can reflect back on our own mental structures and represent them also as concepts. A first approach to how such a mental map might be organised is presented by Ian Kinchin in an introduction to the theory of concept maps, where links between one concept and another build a broader mental structure which in turn becomes a superordinate organiser of the concept (Kinchin, 1998: 1-4).

Mediation also resolves the question of intersubjectivity. Concepts do not have to be the same but they do have to overlap especially in linkages and structures for effective public communication. This is especially so in subjects like mathematics and science where structure, relationship and formal definitions dominate.

This leads to two very interesting reviews of Vygotsky's theory - an amplification of Vygotsky's genetic law, where the intermental is a precursor of the intramental, that consciousness exists "out there" in the social setting before it is integrated into individual consciousness and the observation that the whole idea of a zone of proximal development assumes that in the presence of competent others we are capable of actions beyond our own individual competence (Cole and Wertsch, 1999: 4). The authors point to research on distributed cognition, situated learning and external symbol systems as points of departure for further development of the theory (ibid: 50).

The concept of mediation seems to me to provide a central theoretic support for my initial intuition as a teacher, that the process I was involved with was more to do with the presentation and acquisition of cultural constructs than facilitating pupils' interaction with nature. Cole and Wertsch are also helpful in pointing away from grand theory to work that more directly relates to the classroom. Ideas of situated and distributed cognition (where part of the process of cognition is distributed in artefacts and actions in the environment and linked in time with earlier points in the culture) and of cognitive apprenticeship, where specific processes aid the learner in association with a more competent other.

These ideas link to ideas like contingent teaching, where the amount of support offered to the learner is increased or reduced as the learner gains in competence (Wood, 1989: 78-79). This appears to directly exploit movement in the zone of proximal development and show the use of external scaffolding and the ideas of situated and distributed cognition seem to offer a way of moving from the study of individual tuition to whole-class teaching.

Susan Carey introduced me to the idea of a novice - expert shift in concept formation - indicating that experts attended to different aspects of problems and organised their approaches in different ways (Carey, 1989:109).

However Sara Hennessy points out that the practical applications of this are

limited, since experts and novices do not normally share similar goals nor carry out similar tasks. Direct comparison between expert problem solving and the work of pupil novices is unlikely to be illuminating. In part this is because cognition is situated - the sophisticated mental models of experts are influenced by the social and cultural context in which the problem-solving takes place. (Hennessy, 1993: 1-2).

Her critique serves as an introduction to the ideas of situated cognition; that problem solving is not a process internal to an individual mind, but one grounded in social practice. If the child learns a set of cultural conventions for tackling problems and presenting answers then educational ground-rules operate only in the traditional classroom, considered alien to the external community. This disjunction is fed by the individualist perspective of education, the decontextualised context of academic learning, the divorce of the emotional and intellectual and the formulaic nature of problems (ibid:3).

Distributed cognition argues that cognition cannot be localised within the mind of individuals but is supported and scaffolded by physical and cultural artefacts in the environment examples are provided by language use. Many words such as "I", "you", "here", "there", are indexical - totally dependent on context for meaning. Brown et al. argue that all words have this indexical element and, because meaning develops through activity, they can be thought of as tools. In a domain of knowledge students must use these tools in authentic activity - defined as coherent, meaningful and purposeful within a culture ((Brown et al, 1989: 34-35)

A Vygotskian Paradigm

The issue here is the extent to which ideas of situated cognition would lead simply to a broadening of the context of development to make it more social or if they indicate a collapse of the Piagetian paradigm. The first conclusion would lead to a "weak" social constructivism in which Vygotsky's perspective is simply one of many competing tendencies and it would then

be mistaken to speak of a distinct "Vygotskian" cognitive theory. The second would be strong justification for the investigation of Vygotskian theory to establish its overall plausibility as a general theory of cognitive development.

Are the different aspects of constructivism and socioculturism simply different perspectives explaining the different facets of a common reality? Is what is involved either seeing mind as in the head, learning as cognitive reorganisation and signs as communication as opposed to mind being seen as the individual in social action, learning as enculturation and signs as carriers of social meeting and practice?

Paul Cobb argues that it is the case that we are dealing with different facets of the same paradigm and argues that convergence can be achieved when we examine the problems that each perspective faces. For example, the question of empirical and reflective abstraction, as developed by Von Glasersfeld, can be viewed as partly taking place "inside" as the accommodation of an experienced novelty *and* also as taking place "outside" within the cultural situation and with cultural tools. A further example is taken from Rogoff and the question of internalisation. Rather than seeing a shared understanding as in some way crossing a barrier, she suggests an individual appropriation of each shared practice. This overcomes the difficulty, but shifts the perspective towards an individual constructivism. A proper understanding, Cobb suggests, arises from seeing a movement from foreground to background between each theory (Cobb, 1999: 142).

Rogoff accepts this concept of two perspectives, but indicates that they cannot be achieved by adding a social dimension to Piaget. Rather individual learning must be set in the framework established by Vygotsky. She explains this by a reference to intersubjectivity. For Vygotsky, joint problem solving occurs between partners while for Piaget it occurred within the individual following communication of each other's ideas. However, rather than simply moving from background to foreground Rogoff suggests

that the two theories may explain different cognitive activities. Vygotsky may best explain skills and understanding, while Piaget may best explain shifts in perspective (Rogoff, 1999: 7).

Bauersfeld adopts a useful perspective in supporting Von Glasersfeld's model of communication as mutual adaptation, but goes on to see learning as the subjective reconstruction of societal means and models. One interesting aspect of his perspective is the shift in focus away from the aspects of the situation which are explicit. In mathematics, and by implication, other school subjects there may be a great deal of implicit negotiation about when to do what and how to do it. Bauersfeld suggests that these effects may be at their strongest in the microculture of the classroom. (Cobb, 1999: 138).

Among others, Brown et al. contrast the difficulties of formal learning with the informal success of apprenticeships to develop ideas of cognitive apprenticeship and situated learning (Brown et al, 1989). These approaches seem to be firmly within a Vygotskian perspective and also to link back to earlier studies of the hidden curriculum – focusing attention on what is going on in the classroom rather than what we expect to be occurring. Lave and Wenger extend these conceptions to develop the idea of legitimate peripheral participation. From this viewpoint learners are apprentices who achieve mastery by gradual absorption into a community. However this is not a simple acculturation. They are entering a community of practice in which they both learn by doing and also learn the meaning of what they are doing as they interact with the artefacts of the trade and the other participants. The structure of learning is organised around the needs of the community rather than any formal logical structure, for example a production process may often be learnt “backwards”. Learning in schools is not exempt. This also is a form of legitimate peripheral participation. Often what is learnt is how to be a member of the school community or how to enter the community of schooled adults rather than a specific subject, in the case of physics, for example, entry to the community of practice of physics would take place many years after learning school physics. In the process of

outlining this model of learning Lave and Wenger challenge the possibility of separating what is learnt from the situation in which it is learnt and the possibility of the sort of subjective and scientific learning which Vygotsky extolled (Lave and Wenger 1999: 21-27).

One way forward is to look again at theories which underpin cognitive theory and are often seen as explaining cognition, these theories, of biology, language and computation should be used not as explanations but as frameworks within which thinking and learning occur, constraints on the kind of learning that can occur and, with care, as an analogy for some of the processes of thinking. For example, Sacks' evidence of adaptation by neurone groups offers some support for Jean Piaget's assertion of adaptation at higher mental levels and Carter's evidence of the final steps in neurone development occurring after puberty gives some support to the idea of stages in development (Carter, 1999: 23), (Sacks, 1999: 60).

Bruner saw a need to break from a Piagetian concept of the solitary learner, and initially turned to a computational theory of mind, (Bruner, 1996: 6). The case for a biological and computational theory of mind has been argued in detail by Pinker who drew on the analogy of a Turing machine carrying out simple computations which showed an overall intelligence (Pinker 1994: 78). Pinker also drew on the evidence produced by Chomsky of innate biological mechanisms involved in the acquisition of language and on further evidence of the combinatorial aspects of language and structural imposed by grammar to argue a biological determinism.

To some extent this is beside the point. Rogoff indicates that there is also a strong case for a cultural determinism (Rogoff, 1999: 72), but thinking is clearly emergent from culture and biology and still requires explanation in its own terms. In any case Bruner has argued for a cultural LASS (language acquisition support system) (Bruner, 1983: 27) rather than the genetic LAD (language acquisition device) suggested by Chomsky (Chomsky, 1993: 34). Brown and others point at the indexical nature of words and their reliance on position and total meaning (Brown et al, 1989:32). More recent research by

Bredo draws attention to some of the differences between thinking and computation. The linear steps in a computer programme separate plan from action. In humans plan and action appear one reflexive process and there doesn't appear to be a need for a mapping, with many actions occurring automatically as movement takes place (Bredo, 1999: 30). Sack's introduction of Edelman's TNGS (the theory of neurone group selection), where groups of neurones compete to represent processes has value as analogy which is not at all like the computer analogy (quoted in Sacks, 1999: 58). Adaptationist theories of the brain, such as Edelman's, draw attention to aspects of brain function that must constrain higher levels of thinking. That is, that thinking involves adaptation, involves simple, modular, automatic processes and requires a holistic framework to acquire meaning.

Overcoming the crisis in psychology

Vygotsky offers the outlines of a powerful overarching theory with great explanatory power and utility. It is best understood on its own terms rather than as part of a more general theory of social constructivism. Central to it as a theory in itself is the idea of mediation, present in Vygotsky but not in Piaget. Biological accounts of our behaviour can be subsumed within Vygotskian theory as a base for higher mental functions but have to be rejected as an explanation.

Current work within social constructivism and situated cognition show a great range of study and a power of illumination but do not always articulate well with classroom practice. I hope, by narrowing the focus to mediation and concept formation, to examine thinking more closely linked to the concerns of the classroom.

In summary, a Vygotskian perspective offer the possibility of overcoming the crisis of psychology. It is able to accept that mechanical, automatic, biologically determined processes, especially those of perception and action can give rise to self-determination and self-consciousness. The contradiction

between behaviour and action is overcome by dialectical movement. Thought does not exist mechanically in a brain nor disembodied in a mind. It is constructed both by movement upwards from biological processes and movement downwards from higher mental functions.

A Vygotskian perspective can incorporate the adaptive processes of the Piagetian scheme but, as suggested by Rogoff, it would be qualitatively transformed by the fact that what is manipulated within the new scheme is the sign - an abstract cultural object.

It can be argued quite convincingly that ideas such as situated and distributed cognition and cognitive apprenticeship follow naturally from a Vygotskian perspective that leaves meaning both inside and outside the individual human.

This interpretation of Vygotsky also has the advantage that it resolves the question of meaning. In Piaget's theory meaning was inherent in nature. The adaptive structure of the Piagetian scheme, where reflex became action and action became consciousness would have the end point of logical meaning because there was assumed to be a logical structure to nature and a logical structure within the brain that discovered nature's logic by resolving contradiction.

Finally the Vygotskian theory allows a critical approach to arenas of situated learning. In both Vygotsky and Piaget the learner is an active learner. In Vygotsky's approach the question of intersubjectivity is resolved by a series of adaptations and approximations in which personal, idiosyncratic ideas are aligned with broader, formal, public definitions. One useful aspect of this conception is that it allows for both cooperation and conflict; between individual and individual, individual and group, individual and society and finally between group and group. The aspect of conflict means that contradiction does not have to be resolved. Different understandings can overlap, leaving some aspects of meaning fuzzy and ambiguous.

Knowing in this perspective is a social product arising from social experience of an external reality, enshrined in the view of Lave and Wenger in 'communities of practice' (Lave and Wenger, 1999: 24). It always remains approximate, able to tolerate the idiosyncrasies of individual interpretations but also open to conflict with individual experience and vulnerable to our ability to think reflexively and carry out metacognition.

Of course much of this remains speculation. The construction of a convincing overarching theory is well beyond the scope of this thesis. What my own exploration of, and speculation about, theories of consciousness does to is provide a scaffolding on which I can base an investigation into the process of learning in the classroom, while making my own position as clear as possible.

Conclusion

The task now is to narrow down the perspective to small scale processes that can be observed and operationalised. I see a natural small-scale process as being the process of concept formation.

Vygotsky has already given a broad outline of this process in an experimental setting. Characteristics are associated with words as empty concepts. The characteristics gradually structure first as impressionistic heaps associated only by immediate perception, then as complexes grouped around some central perception, later as pseudo concepts which collapsed when challenged and finally true concepts.

Another valuable idea to arise from Vygotskian theory is the idea of a zone of proximal development. In brief this is the gap between tasks that the pupil can achieve unaided and those that she can achieve with support. This

is assumed to hint at the buds of developing concepts and to measure the educability of the child. It is mainly used by Vygotsky to illustrate the importance of teaching and of culture in the learning process, rather than viewing learning simply as a process of maturation.

The ZPD is widely used today. It is used directly in tutor-student situations. In classrooms it is often used to justify forms of scaffolding – teaching and learning aids in the form of diagrams, models and so on, although the theoretical justification is rather weak, at some distance from the original conception and pointing with rather a broad brush at a whole series of teaching aids.

I want to look more closely at the process of concept formation and to theorise this as a developmental space. If I am successful in theorising this space I believe that it may offer insights into the development and use of pedagogical strategies and teaching aids in the classroom.

Chapter 3

Modelling a developmental space

Introduction

In this chapter I want to look more closely at the idea of a concept. I hope to resolve some of the ambiguities involved by comparing the Piagetian perspective on the formation of a concept with the Vygotskian perspective.

Further clarification is sought in this chapter from looking at research studying misconceptions or alternative conceptions. My interest here is the possibility that there may be limitations on the way in which we can approach areas of knowledge, some of which may be imposed by the internal structure of language. Other restrictions will be imposed by individual worldviews into which new concepts have to fit and the budding concepts may also be constrained by modes of thought that help to determine the nature of the concepts formed and the relationships between them. Concepts may fit along dimensions between perception, language and structure. Rather than being determined by formal definition they may, I argue, exhibit a dialectical nature, a flux in which they both determine and are determined by the broader mental constructs within which they sit. It will be necessary to consider the extent to which concepts are situated in particular environments and the extent to which

there is a tension between school knowledge, everyday knowledge and formal science concepts.

Finally I want to sketch a model of concept formation which will illustrate my initial ideas about the elements of a developmental zone and suggest methods of investigating such a zone.

A Piagetian model

I considered, early in the study, a ready made model of concept formation which aimed to link Piagetian and Vygotskian approaches. This was the model of Cognitive Acceleration through Science Education (CASE) presented by Phillip Adey and Michael Shayer. I was presented with a guide to their model on a training course provided by the Northern Irish Southern Education and Library Board (SEELB). In outline the Adey and Shayer model suggested that only certain levels of cognitive difficulty led to concept development. Simple events were assimilated into existing models, very complex events were ignored while relatively difficult to understand events led to Piagetian accommodation and the formation of new concepts. The task of science teaching was to produce cognitive conflict. Class or group discussion of the processes involved would lead to metacognition and bridging which would generalise concepts and link across subjects (Adey and Shayer are summarised in *CASE* notes, SEELB Science Advisory team 1995: 13).

I rejected this as a model on the basis that I did not find it convincing as a model of Vygotskian processes. My reading of the model contained in the *CASE* literature was of a solitary learner interacting directly with nature and communication with others then leading to a more 'Vygotskian' metacognition. A Vygotskian process would involve interaction initially through cultural tools and a degree of intersubjectivity. Thus, even if the results in terms of educational attainment were as the authors claimed, the claim that

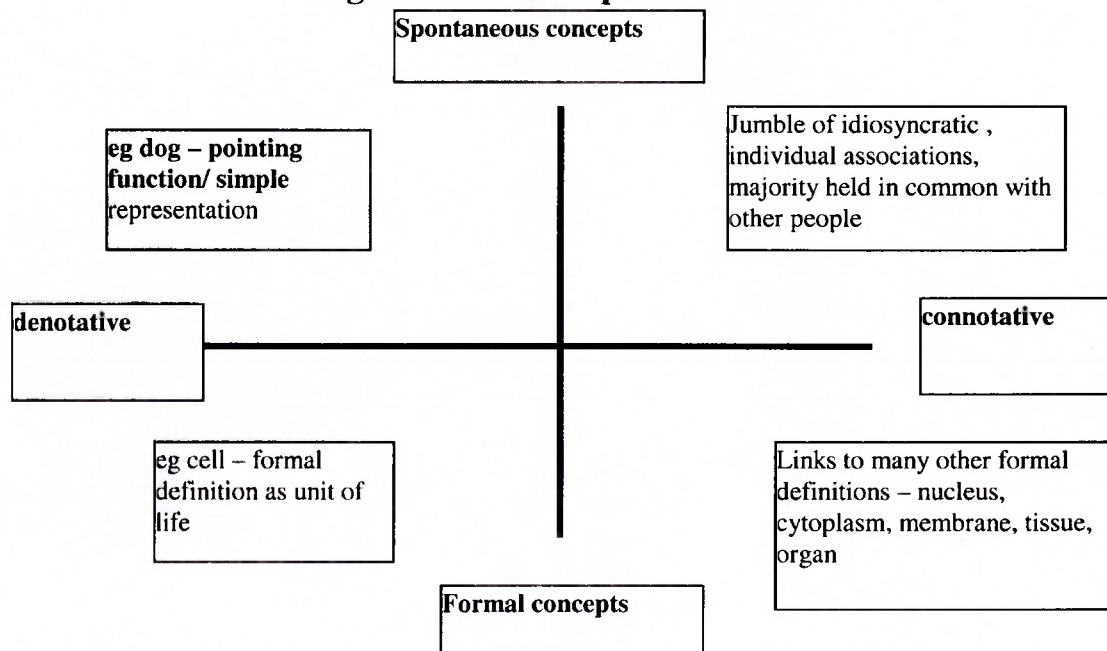
this proved the model of concept formation advanced would still be open to all the theoretical criticisms advanced of the Piagetian model generally. It seemed to me that the Adey and Shayer representation had all the hallmarks of a Piagetian model of the solitary learner interacting with nature, with language and culture playing a subordinate and secondary role.

As an alternative I aimed to construct my own view of concept formation and movement in a developmental space and felt that I should begin at the very beginning with the definition of a concept.

Concepts have a denotative aspect (sometimes called an identity concept) and a connotative aspect (sometimes called an equivalence concept. The concepts (or categories) can be understood as particular mental constructs for representing and organising the external world, standing alongside frames which represent the physical environment and scripts representing appropriate modes of behaviour in into natural concepts formed spontaneously by individuals and formal, rule based concepts (Taber, 2002: 11 and 27).

We may think of dimensions associated with concepts as follows:

Figure 3.1 – concept dimensions



The extent to which new rule-based concepts are formed in schools can be taken as a measure of learning, especially in subjects such as science (ibid, page 12.)

The Piagetian approach to cognition suggests a solitary learner. The concept develops in relation to adaptive patterns of perception and action, initially genetically determined, which represent an external reality. The complexity and depth of the concept and its relationship to other concepts is the result of a process of maturation within the individual. Piaget saw the mature concept as resting on formal logic, because formal logic was 'out there' in nature waiting to be discovered by the learner. It would only be possible for an adaptive process to end in a logical structure if the logical structure were built into nature or if it were built into the nervous system – which would essentially be the same thing. Piaget had some support for this idea in his understanding of the biology of evolution, where random processes led to complex biological forms. Lunzer argues in opposition that formal logic was only one of a number of cognitive strategies and that many adults never arrived at a stage of formal logic (Lunzer. 1989: 27). The role of language was to communicate ideas in a relatively neutral way, the words denoting public agreement between a range of private concepts which overlapped.

Initial perception

The Vygotskian approach to concept formation is not in contradiction to Piaget. It would tend to support some sort of adaptive process in learning in animals and in prelinguistic children. Modern theories in experimental psychology, such as Edelman's Theory of Neuronal Group Selection (TNGS) allow us to picture the initial aspects of concept formation (Edelman's theory is outlined in Sacks, 1999: 58). Perception and action are built out of subtasks which are largely automatic, based on reflexes, some of which are "hard-wired" by

genetics. Eysenck and Keane report that two separate neural systems, in different parts of the brain control different aspects of perception. One element controls object identification or what? and the other spatial identification or where? (Eysenck and Keane, 2000: 69-76). These subtasks assemble larger structures extremely rapidly, yet eventually these automatic processes lead to consciousness and self-determination. It may be useful then consider an initial level of concept formation as being initial perception and action. There is strong evidence to suggest that mental activity at this level is made up of a limited number of 'subroutines', for example, the recognition of lines, shapes, edges and so on (Carter, 1998: 39). These provide a 'filtered' representation of external reality. There is also evidence that these processes are modular, with different regions of the brain working together to create an ensemble (ibid). Daniel Dennett explains that it is this sort of ensemble that is consciousness. Descartes suggested a dualist mind/body junction in the pineal gland. Many modern theories cling to a Cartesian materialism that centres consciousness at a point in the brain. Dennett argues that information on nervous reaction times indicates that no such central processor can exist. Instead, modules produce 'multiple drafts' representing external reality which are selected by adaptive processes in the brain. The ensemble of these represents a narrative stream of consciousness which we can sample and examine as conscious thought (Dennett 1991: 105 – 115).

Mediation

However human thought does not consist of simple mental representations of the external world. Human thought is dominated by word and sign. The unique aspect of Vygotsky's theory lies in the idea of mediation. Once the child acquires language adaptive processes in concept formation no longer occur by direct interaction with nature but are mediated by the word, part of a repertoire of cultural tools that enabled what Vygotsky called the higher mental processes

and enormously amplified human cognition. We can initially approach the idea of a developmental space by saying that it is layered by these 'higher' and 'lower' mental functions. Lower processes of perception, action and memory we share with other animals, especially with the Primates. Higher processes are specifically human and are built out of psychological and cultural 'tools' such as sign, language, mnemonic systems distinguished from other tools and techniques of human culture in that they point 'inward' to restructure the initial processes into human thought (Vygotsky, 1978: 54). Higher mental processes are built out of lower processes, but cannot be reduced to them because their construction takes place in part outside the individual in a social and cultural dimension. In any case, as the higher processes develop they transform the lower processes so that they operate on the sign rather than by direct interaction with nature (ibid: 26).

The central element Vygotsky's perspective is the word. Thought takes on a specifically human character through the word. The word is initially an empty concept - it points at an external object or at part of a discourse. The learner accepts the word in the expectation that meaning will follow (Vygotsky, 1971: 57) At this point the concept is 'fuzzy' – humans can tolerate a great deal of ambiguity and Vygotsky suggested that a whole series of ephemeral structures such as 'heaps' and 'complexes' develop in the early stages of concept formation.

Vygotsky defines stages in concept formation as follows;

- Heap. Groupings formed by chance by being linked through the child's perception.
- Complex. Groups formed by real, concrete, immediate links but not by abstract or logical relationships.

- **Pseudocomplex.** In the pseudocomplex the outcome is identical to that for the concept, but the mental process is that of the complex.
- **Concept.** Concepts form spontaneously and unconsciously from pseudocomplexes because the child's thinking is constrained by the word and the public connections between words that they gradually make their own (ibid: 59-68).

The word serves a mediating function. It allowed the learner to order and structure perception internally via the sign. The word as sign is much more than a pointer. It immediately transforms human thinking into thinking about abstractions. Vygotsky makes the point that perception is initially integral. With speech it becomes analytical (Vygotsky, 1978: 33). The word is a psychological tool bringing to the situation the scaffolding of the existing structure of grammar within the language. The word points and names, embedding within a noun phrase or a verb phrase and attaching to itself the characteristics and expectations that the grammatical structure of the language encourages.

The word

In Chapter 2 I outlined Stephen Pinker's belief, following Chomsky, that humans possessed an innate mechanism for acquiring grammar. In *The language instinct* he explains in more detail what he describes as a "tree-like" structure to language. A sentence is made up of noun phrases and verb phrases. The phrases are made up of mini phrases called X-bars made up of individual nouns, verbs and modifiers. This allows children from an early age to generate infinite numbers of valid sentences with only limited errors. More importantly, from the viewpoint of this investigation, it allows a ready acceptance of highly

abstract concepts arising simply from the position of the word within the sentence structure (Pinker, 1994: 284-287). The situation and broader narrative structure allow opportunities for more cues about the concept.

My understanding is that we can look at pre-human reasoning as being a direct interaction with nature based on action. Piaget's scheme seems to me to explain convincingly how a process of adaptation can modify actions that are initially instinctive. The simplest approach to mediation is to see the scheme repeating itself, but this time manipulating not nature or objects, but manipulating a sign. This immediately means a higher level of abstraction because the sign represents not an object but a class of objects. Not only that, the word is also an 'empty concept', to a large extent malleable and able to be used to build an endless range of structures and linkages. This means a more complex mental map which does not link object to object or action to action but builds a representation of a rather fuzzy private world where concepts are defined by their relationships. Metacognition becomes possible, as we can reflect back on our own mental structures and represent them also as concepts. Intersubjectivity establishes initial, public concepts which evolve into private concepts. Public and private concepts do not have to be the same but they do have to overlap especially in linkages and structures. This is especially so in subjects like mathematics and science where structure and relationship dominate. We can picture spontaneous concepts as being embedded in a social situation and as relatively autonomous and fuzzy. Formal concepts are embedded in the logical structure of a subject area. These are situated also, but in a different way, not being embedded in an immediate social situation but the historical product of the interaction between human society and nature.

In the Vygotskian view the word mediates in that it allows a collective, intersubjective, definition of the concept. At this stage the emerging concept is highly situated. It exists within a particular context and may dissolve back out

of consciousness. This local structuring is supported by what Mithin calls intelligences (Mithin, 1996: 143) but what Bruner might see as narrative structures (Bruner, 1996: 95) and what appear in Osborne and Freyberg as categories or associations (Osborne and Freyberg, 1985: 29). The three perspectives all diverge in imagery. Mithin pictures innate mental modules such as social, technical and natural history intelligences. Bruner pictures an innate readiness to grasp narrative structures and Osborne and Freyberg see spontaneous concepts formed independently of schooling. What they all have in common is a belief that there is an initial, innate structuring that has to be taken into account when undertaking formal instruction.

Newly formed concepts gain in stability as they link to other concepts, undergo a process of accommodation and become structured in superordinate concepts (Vygotsky, 1971: 92-93). Linkage to other concepts in the classroom is associated with a background or assumed structure to knowledge in the syllabus and in assessment. One concept can be seen as close to another or they can be seen as based upon preceding concepts or as serving as the foundation for concepts yet to be formed, for example fertilisation may be based on a simpler concept of mating and itself be the base for a concept of genetic transfer. The concept itself can gain in detail and structure. This often occurs in the classroom through exposure to a series of examples or case studies, for example burning a number of elements and writing word equations until the concepts of oxidation and oxides have formed. Greater detail and exposure to exemplar material often leads to a greater generalisation and abstraction. It might also be expected that a process of accommodation may take place. Piaget defined the acceptance into a mental structure of new ideas as assimilation – the modification of the mental structures is called accommodation (Piaget and Inhelder, 1969: 6). An example of accommodation would be someone who believed that air caused burning who modified their ideas to understand the role of oxygen. New concepts are unlikely to fit snugly with the old and both new

and old are likely to change in the process of assimilation. This may involve aspects of cognitive conflict, but only to a limited extent as long as the concept remains structured within a school subject boundary. The processes should be seen as adaptive and to involve logic only to the extent that the subject demands it – a term in mathematics with different meanings might cause difficulty, but a word in a language lesson with two meanings would occasion little surprise. The end result of such a process should be linkage to superordinate structures. These should be thought of as nested, in the sense that a concept might have a stable place within a subject while co-existing with a contradictory view in everyday life – an example of this can be found in Susan Carey's description of everyday Physics (Carey, 1989: 107). There also appears to be a more generalized, historical situatedness in that the evidence of Carey seems to indicate that we carry individual models, adopted from the overall culture, of our own understanding of, for example, 'everyday Physics' which structures our expectations of what will happen in a given situation and how it might be explained (ibid).

Vygotsky saw formal logic as one of the higher products of human culture rather than arising naturally. Mature concepts were the product of schooling and were held in sharp contrast to spontaneous concepts. What defined a mature concept was not simply logic but its embedding in more complex systems of ideas and philosophies. Because, in the Vygotskian view, there is no predetermined outcome in concept formation there can be no single definition of what a concept is. Instead Vygotsky attempted to classify various stages in concept formation - primitive 'heaps', structured 'complexes', pseudo-concepts and so on.

A more general level of cognitive conflict might be expected with the development of what Vygotsky called the "mature concept", where abstract,

scientific knowledge and more subjective everyday understandings are united (Vygotsky, 1971: 92-93).

Contradictions between domains or subject may be resolved once we move away from school knowledge – for example into communities of practice as outlined by Lave and Wenger or where elements of school knowledge are absorbed into a more general philosophy or world view (Lave and Wenger, 1999: 21). For example, when training to be a tailor the process is more in the nature of being absorbed into a culture than gaining instruction. Aspects of the process are learnt ‘backwards’ from a logical perspective and the concepts formed appear more holistic and spontaneous.

Stephen Dehaenes's investigation of what he calls 'numerosity' in babies, reported in chapter 2, is illuminating. The babies appear to focus attention on situations where number is not conserved. For example, their gaze is directed longer at situations where two objects are hidden but when the screen is removed one object or three objects are revealed. Dehaene calls this expectation of number conservation 'numerosity' and suggests that it is innate in the biology of the baby at birth (Dehaene, 1997: 49). This idea seems to have many aspects in common with Piaget's idea of the scheme. It is also, clearly, quite distinct from the concept of number. The historical record shows that number is a cultural concept that evolved over thousands of years, with many halts and difficulties such as the concept of zero and of place value. Not only does 'numerosity' mirror the Piagetian scheme and number mirror the Vygotskian approach, it also appears that in human development number replaces numerosity and we manipulate the cultural construct rather than the vague perceptions of our prelinguistic stage.

Children's conceptions

A survey by Susan Carey quoted in *Making Sense of Secondary Science* (Driver et al) indicates that at six and below many children do not understand gender constancy and believe that gender is a matter of choice. Many believe that babies are already existing and do not understand questions about their origin (Driver et al 1994: 48). The conceptions that form seem to follow a pattern. Initially it is thought that babies are manufactured from parts or that food that the mother eats is converted into a baby. Very often animism is a feature of conceptions, with children imagining that sperm and eggs are capable of deliberate actions. An agricultural model, where a sperm or egg is planted in soil in the womb, is commonly held (ibid, 49). Interestingly, many of these concepts were held historically as the modern scientific conception gradually developed.

At age eleven or twelve many children understand the role of intercourse and that egg and sperm are joined. The fact that there are significant differences between the understanding of middle class American children and a more general survey of US children and also sharp differences between the views of children in different countries indicate a strong cultural dimension to concept formation in this field (ibid).

In a study by Tamir and al reported in Driver (ibid) it appeared that most children were able to sequence stages of germination and embryo development. Only 66% of the sample however believed that a seed was alive. Again this was strongly situated, with only one pupil in an agricultural college rejecting the idea of life in the seed (ibid, 50).

Other studies showed a tendency to equate copulation and reproduction. Pupils found it relatively easy to identify examples of sexual reproduction in animals but often denied that sexual reproduction occurred in plants. These ideas were

relatively immune to teaching and were linked to disinterest and a general lack of concept formation in this area (ibid).

Much of the interest in science misconceptions is from a pedagogical viewpoint. The intention is to find a starting point on which the teaching of formal scientific concepts can be based. Driver et al present a pedagogical model somewhat similar to Adey's model of concept formation (Adey, 1994: 76). Elicitation of student concepts leads to conflict situations and the restructuring of the student's concepts in the direction of scientific consensus (Driver et al, 1989:88). Osborne and Freyberg argue for 'student dominance' of the curriculum so that student ideas and attitudes may be modified (Osborne and Freyberg, 1985: 85 – 92).

My interest in student misconceptions is focused in a different direction. By studying the range of common misconceptions I am seeking any hints of internal mental structuring that guides the way in which concepts are formed. Is there such a thing as a 'folkbiology' and if so what would its structure be?

Cognitive domains

Susan Carey has done a lot to clarify this issue through her review of the idea of cognitive domains. She quotes Chomsky who sees cognitive domains as a number of innate modules, each with a distinct set of phenomena and core principles (e.g. for language the core principles would be rules of grammar). Carey agrees that there are innate structures, but does not accept that these amount to cognitive domains. Rather there are more basic modules controlling aspects of perception and language.

Carey posits the idea of intuitive theories which are defined by ontological commitments plus modes of explanation (Carey, 1996: 190). The entities organised by the theory are collectively domains. From this perspective we can define a 'folkbiology' which is internally constructed by age 10 – earlier ideas of living and non-living are not extensive enough to merit this description in Carey's view. *At the outset of language learning children assume each entity can have only one essence* (ibid, p194) (so taxonomy is built as a result of language). Many of these domains share with early historical forms of biology an animist conception – the idea of a vital force that animates living matter. One consequence of this line of reasoning is that the folkbiology is not innate, but is built from earlier cognitive domains. In this case, Carey argues that the parent domain is folk psychology (ibid: 210).

From a different direction Mithin argues that social intelligence must have been one of the first forms of intelligence to appear in human evolution, and that indeed social living may have forced intelligence. He argues further that early biology developed from social intelligence and was characterised by animism and anthromorphism. Finally he argues that it was the development of language that allowed different domains of intelligence to link together as the basis of modern human cognition (Mithin, 1996: 99).

Keith Oatley, following earlier work by Peirce, suggested that the way in which we form concepts may be constrained by a relatively small number of reasoning strategies. Peirce defined 3 mechanisms of reasoning; deduction, induction and abduction or hypothesis (Peirce, 1957: 128-129).

- Deduction

Rule: all beans in the bag are white

Case: these beans are from the bag

Therefore result: these beans are white

- **Induction**
 - Rule:** these beans are white
 - Case:** these beans are from the bag
 - Therefore result:** all beans in the bag are white
 - **Abduction**
 - Rule:** all beans from the bag are white
 - Case:** these beans are white
 - Therefore result:** these beans are from this bag
- (ibid)

Oatley argues that the most common form of reasoning is abduction and that this is selected for in evolutionary history because it works well in commonplace situations where the actor has a lot of background knowledge. It works well in narrative forms also because the narrative is a closed world, without the endless surprise of the real world. From this perspective narrative can be considered a form of emotional modelling of personal and social situations, driven by abduction (Oatley, 1996:128).

Feldman and Kalmar suggest that a further structuring of ideas occurs through genre, which acts as a lens through which we interpret the meaning of text (Feldman and Kalmar, 1996: 108).

Oatley goes on to argue that:

“By contrast, science has procedures from which the personal is, in a sense, factored out and by which consensual

truths may be transmitted. It involves a more elaborate set of inferences. Peirce proposed that doing scientific research needs to use his three kinds of reasoning in a specified order. First, one uses abduction from observations to a possible explanation or hypothesis. From this, one deduces a fact not yet observed. Then several tests of such fact are put together with the original observation to make a generalizing induction."

(Oatley, 1996: 134 drawing on Sebeok and Umiker-Sebeok 1983)

In fact Oatley argues, there is evidence to suggest that the practice of science is socially distributed, with different groups of scientists providing different processes to what is eventually announced as an individual discovery (ibid: 137 – 8).

A parallel position is taken by Bruner, who argues that there are Galilean and Aristotean modes of thought, one lending itself to the modes of science and the other to narrative (Bruner, 1996: 95 –98). The narrative form is more widely used and more closely linked to innate social skills of telling and understanding stories, the Galilean, also called the 'logico-deductive' mode by Bruner, is seen by him as a more recent cultural invention drawing on different mental skills.

A Vygotskian model

In my view Vygotsky would have seen the process of mature concept formation as being completed when the everyday, idiosyncratic concepts of the individual were fused with the formal, structured definitions of science to form one overarching understanding, illuminating both the experiences of private life and the more abstract understanding of science. A further element of the mature

concept would be a level of metacognition. The pupil would not only be able to use the concept to solve problems, but could reflect from the 'outside', able to examine their own understanding and 'know that they know'.

In order to complete the base for a Vygotskian model of cognition we would have to take account of the growing literature, arising after Vygotsky, that indicates the highly situated nature of much cognition. Lave and Wenger go as far as to say that forms of cognition do not exist separately from communities of practice and are a function both of the learner and of the social environment in which they exist and carry out specific mental functions (Lave and Wenger, 1996: 145).

A tentative initial impression of a Vygotskian model of a developmental space would look like this:

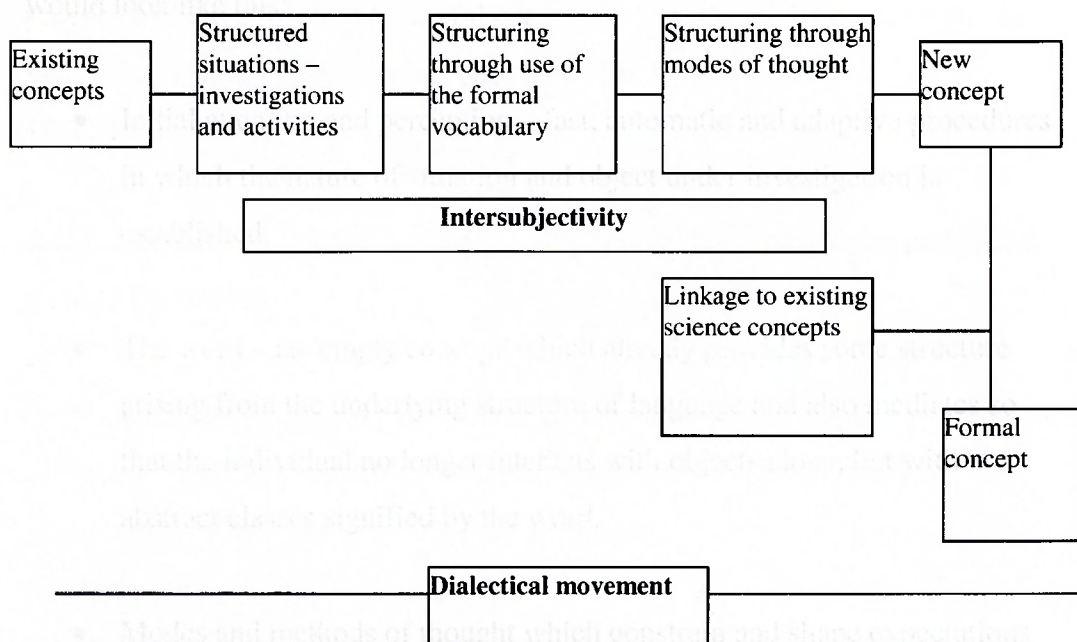
- Initial attention and perception – fast, automatic and adaptive procedures in which the nature of situation and object under investigation is established.
- The word – an 'empty concept' which already provides some structure arising from the underlying structure of language and also mediates so that the individual no longer interacts with objects alone, but with abstract classes signified by the word.
- Modes and methods of thought which constrain and shape expectations about what the nature of a new concept might be.
- The social situation – the expectations associated with the social context in which we find ourselves.

- Outcome – A new concept is one of a range of outcomes which include heaps, complexes and pseudo-concepts. They may be temporary or permanent, integrate with existing knowledge structures or reinforce existing beliefs in opposition to school knowledge.

Finally Vygotsky, I feel, would argue that the whole process was dialectical. That if it were true that the initial perception led to the final concept, it was also true that the existing conceptions structured initial perceptions.

An interesting footnote arises from this model right away. It suggests that cognitive conflict and metacognition are rather specialised mental activities that only arise when formal logic is engaged. I will look at this implication again later in the study.

Figure 3.2 –A developmental space



Reproduction in Secondary Science

What does the initial model of a developmental space tell us about reproduction in secondary science? The starting points would be everyday knowledge, which would almost certainly be knowledge of human reproduction, understood from

a 'folkbiology' sense, with misconception such as confusing copulation and reproduction and sperm with semen. Alongside the everyday conceptions we would expect a separate 'science' understanding based on an asexual life cycle diagram, used as a major element of the explanation of reproduction in the primary syllabus. We might also expect a relative lack of concept formation in relation to plants.

Reproduction in general, and plant reproduction in particular, have associated with them an extensive technical vocabulary. A Vygotskian perspective would indicate that pupils would accept this vocabulary automatically, using the words simply as pointers to indicate, for example, the parts of a flower and going on to develop linkages and connections between words to build initial heaps and complexes that would allow concept development. We might expect these local, temporary linkages to receive scaffolding from standard science tools such as models and labelled diagrams, from techniques such as structured observation and the use of the hand lens and science concepts such as structure and function (the idea that the shape of living structures is associated with the processes carried out – for example that the canine tooth is pointed because it carries out a biting and tearing function).

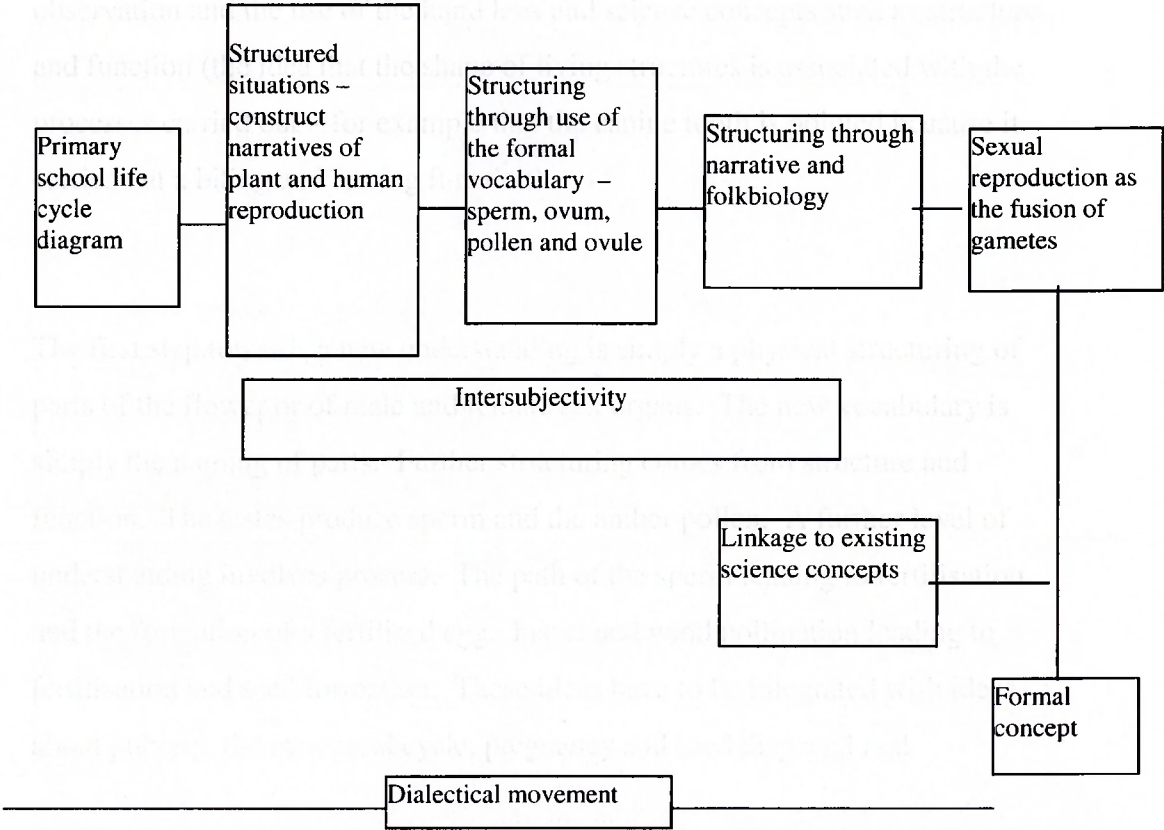
The first step towards a new understanding is simply a physical structuring of parts of the flower or of male and female sex organs. The new vocabulary is simply the naming of parts. Further structuring comes from structure and function. The testes produce sperm and the anther pollen. A further level of understanding involves process. The path of the sperm leading to fertilisation and the formation of a fertilised egg. Insect and wind pollination leading to fertilisation and seed formation. These ideas have to be integrated with ideas about puberty, the menstrual cycle, pregnancy and seed dispersal and

germination in plants. At each stage we would expect, following Vygotsky, that the appropriate concepts would emerge first in a public, intersubjective way before being internalised by the individual.

We can think of stable concept formation occurring when the new concept of plant reproduction links with the concept of human reproduction. Both structures rest on a substructure of technical terms and themselves rest within a superstructure of generalization. The formal overarching science concept is where male and female gametes, human, plant or animal, fertilize to produce a zygote. These overall abstractions can be used to develop understanding of unfamiliar life cycles such as that of the frog or to understand the development of a reproductive science in areas like agriculture.

Most secondary science departments ‘do’ reproduction in a fortnight. It appears unlikely that most pupils would form mature science concepts in this time.

Figure 3.3 – A developmental space for reproduction



Conclusion

In this chapter I have tried to outline the mental processes that would be involved in the formation and assimilation of a new concept and that therefore would constitute a developmental space. The task arising from this is the need to operationalise the model so as to provide research instruments and a research programme. To begin this process I will return to Vygotsky and look at his concern with research processes which he summarised as "the crisis of psychology". He suggested that existing research instruments were unable to overcome the division between humans as subjects and humans considered as objects but that dialectical materialism provided in principle a method of overcoming the crisis.

Chapter 4

Developing Methodology

Introduction

In chapter 3 I outlined a model of a developmental space, attempting to describe the processes that lead from initial perception and action to the formation of a mature concept. In order to develop a methodology through which I can investigate such a space I must now give more detail about the nature of a Vygotskian perspective and attempt to show what a dialectical materialist position might be defined as in relation to other methodological approaches. I will outline my idea of the 'structured situation' as a research tool, indicate the extent to which this might be considered a case study approach and how it led to specific methods of data collection. I will briefly outline the implications that my approach has for data interpretation and also outline the ethical position that flows from the above.

Vygotsky's approach to methodology

Vygotsky began with an ontology of materialism and an epistemology of social constructivism – so these are also my starting points in adopting a Vygotskian perspective. Vygotsky's concern with a theory of consciousness was matched by a concern with methodology. In his view a fully developed science would

develop a number of core concepts and models and these would be linked to a distinct methodology. For Vygotsky, the evidence for a crisis of psychology lay partly in the lack of agreed models and procedures (Vygotsky, 1926: 4) and partly in the fact that the different models contradicted each other (ibid: 11). In fact, as John Searle has remarked, in the absence of such agreement subjects tend to remain within the realm of philosophy rather than science (Searle, 1999: 158). From a philosophical perspective the crisis of psychology was illustrated by Vygotsky as lying between the old dichotomies of the ideal and the real. He saw the dichotomy as being resolved by the application of dialectical materialism to the crisis in psychology (Vygotsky, 1926: 5).

I have already given a broad outline of the dialectical approach in chapter 2. The Marxist perspective is often ignored in many outlines of methodology. In others it is listed, only to be dismissed. For example, Slife and Williams list Marxism as one of a number of structuralist approaches. They criticise Marxism as explaining phenomena in terms of assumed structures that are not themselves open to examination and of offering a materialist reductionism that leaves no room for individual consciousness or action (Slife and Williams 1995: 52).

There are two problems with this approach. The first is that the critique offered is a critique of historical materialism, which is indeed part of Marxism, but it is not a critique of dialectical materialism, which Marx adapted from Kant in order to avoid the problems presented by a purely historical materialism. A second problem is that when dialectical materialism is discarded and positivism is found insufficient, the search for other approaches tends to converge on postmodernism. For the postmodernist, the individual acting in a social setting is the irreducible element of meaning (ibid: 56). There is no appeal to reality, simply a demand for textual coherence within each individual perspective. As

Slife and Williams themselves point out, postmodernist relativism removes the possibility both of science and of an explanation of morality (ibid: 58).

Vygotsky wanted to adapt the Marxist method to psychology, and believed that in the realm of theory he had developed the beginnings of a dialectical materialist approach through his concept of word/meaning, a contradiction that moved outwards to make formal speech and inwards to the informal and idiosyncratic realm of thought (Vygotsky, 1978: 54). He searched also to find a dialectical methodology. This proved much more difficult to identify, in part because there is not one single method of inquiry, a single scientific method but rather a range of scientific methods which are used in an empirical fashion by all scientists (Cohen and Manion, 1989: 20). Cohen and Manion suggest however that there is a hierarchy of methods from simple observation through to mathematical analysis of rigorous experimental technique, and the range available would be restricted by the level of development of the science (ibid: 21).

Theory and methodology

In practice all the approaches to psychology have had linked to them a central methodology by which they have tried to develop a distinct science. Gestalt psychologists like Koffa relied primarily on a method of introspection (Koffa quoted in Eysenk and Keane, 2000: 24). The preferred method of the behaviourist Skinner was the experimental method, made objective by the rigid exclusion of any consideration of meaning and a concentration on the relationship between input and output (Wood, 1989: 4). Piaget used the experimental method to convert action into meaning, or, more exactly the ability or inability of the child to construct meanings in given circumstances. This was made possible by the assumptions of the Piagetian theory, which

assigned to the child a certain level of understanding within the Piagetian categories. Piaget's approach was questioned by Donaldson. Essentially her work, and the work of her colleagues, showed that even small changes in the experimental conditions led to major changes in the outcome. The explanation advanced was broadly that the child, in all the stages of the experiment, assigned meaning and that therefore the tight control of variables which linked directly to a particular outcome or set of outcomes as required by Piaget's experimental method would not be possible even in principle (Donaldson, 1993: 171).

The use of naturalistic observation from the anthropological tradition was a reaction within the social sciences to the failure of the positivist approach to explain the meaning of social situations and activities. The use of narrative to observe events as they happen in some detail allows a thick description which turns on its head the reductionist method used in the physical sciences. This allows the researcher to reflect, classify, search for pattern and develop grounded theory. The difficulty then is to break from subjectivity.

Methodology and meaning

It can be argued that, while the work of Donaldson et al is recognised by educational researchers as a classic piece of research and the negative conclusions in relation to Piaget's research methodology are clearly understood, the positive aspects of the research and the sort of methodology that Donaldson's work points towards are not so clearly understood. As Donaldson points out, children are perfectly able to obtain meaning from situations (Donaldson, 1987: 21) and it therefore seems likely that it would be possible to construct structured situations in which the situation is constrained in the expectation that only a limited number of meanings will emerge and in which it would be possible to elicit children's understandings without seeking that tight

control of variables required by a positivist approach. This approach would be to a certain extent dialectical in that it would not reduce to simpler behavioural elements but would be best understood by constantly shifting perspective between behaviour and meaning. It would not be a postmodernist approach in that the child's understanding would not stand by itself but would be compared to the concepts of science, seen as representing a more abstract and generalised representation of the natural world.

On re-reading Vygotsky it seems to me that there are hints of this sort of approach in his work. His biographers complain about the lack of detail in his experimental work. Where he does give details they indicate not a fine focus on procedure but the structuring of a broad situation which has been limited in some way, as with his concept blocks, and where the experimenter awaits the emergence of meaning. There are also indications of interviews and conversations where the child's understanding is obtained simply by asking for their meaning. Above all, there is evidence of a holistic approach where the overall coherence of the observations, of the theory and of their interconnection is seen as lending authority to the Vygotskian perspective. Michael Cole and Sylvia Scribner acknowledge that the lack of detail in Vygotsky's work was due to the fact that much of it was in the form of pilot projects intended to map out areas for investigation and carried out under the pressure of Vygotsky's illness. However they go on to indicate a range of techniques applied by Vygotsky which he called the 'experimental – genetic method'. Vygotsky believed that the aim of psychological investigation should be to make visible hidden mental processes. The investigation should make available the maximum opportunity for the subject to engage in a variety of activities that would allow such observation (Cole and Scribner, 1978: 13).

Later work, such as the work of Osborne and Freyberg, has used similar techniques of structured situations and relatively straightforward interview

without the assumption of a great deal of overarching theory. Osborne and Freyberg describe a system of 'interviews about instances'. To find children's views about the concept plant they present line diagrams and ask the pupils about their status as plants. These were piloted and the diagrams changed until the researchers are sure they are recording the range of views present in the population – a technique that does not fit well with the constancy of variables demanded by positivist approaches. In a similar technique by the same researchers called 'interviews about events' the children are presented with situations, for example, light shining from different objects and presented with restricted outcomes from which they must select a response. From my perspective the interesting thing about the techniques is that, although they are seen as interviews, they have something of the aspect of experiments in the control and restriction of the situation. However what is controlled and restricted is not variables but meanings (Osborne and Freyberg, 1985: 6-8). These techniques have tended to disapprove Piaget's idea of stages, to show that the elicitation of pupil meaning is relatively straightforward, that only a fairly limited range of meanings are provided and that these meanings given indications of broader structuring of concepts into superordinate structures such as the idea of animism in biology (ibid, 32).

Structured situations

I intend to investigate the possibility of a developmental space through a range of procedures I will term structured situations. A structured situation contains within itself the elements from which a concept (or a range of concepts, extending from heap to mature concept) can be constructed. However the situation can only act as a scaffolding and the concept requires the activity of an individual or group in order for movement along a developmental space to take place and a concept to form. The actual use of structured situations will divide into the semi- structured interview and the structured task in the classroom.

The interviews are conceived of as semi-structured because of earlier experience in a pilot study of using unstructured interviews. These were found to produce too wide a range of responses – pupils seemed unable to determine the meaning of the situation and tended to retreat into silence or to respond with broad generalizations, on occasion based on an ontological substrate such as teleology. It seems self-evident that a tightly structured interview would tend to rule out the internal cognitive construction that I wish to observe. The structured tasks in the classroom are seen as a much looser constrain on concept development because of the greater complexity of social interaction in the classroom.

Structured situations can accommodate the adoption of a dialectical materialist position because we are able to look at each situation from different perspectives without falling into the confusions of an empiricist approach. Unlike postmodernism, dialectical materialism does not allow multiple perspectives of equal value. Rather situations are seen as fitting within two poles of a contradiction. To the extent that the situation is experimental, resting on a tight control of variables then we are at one end of a dimension – that of behaviour, with the person to object. To the extent that the situation is a social setting, resting on the intentions of the people involved then we are at the other pole of the contradiction – that of meaning, with the person as actor. We thus have the possibility of triangulation within each situation and of a further triangulation between situations. Slife and Williams object to such pragmatism on the grounds that the research now needs an overarching theory to explain the pupil as object in the interviews and the pupil as agent in the classroom observations (Slife and Williams, 1995: 45). Other researchers, such as Bird claim that an eclectic approach using different methods allows for triangulation (Bird, 1992: 127-43) or that case study methods serve a valuable role in allowing pilot studies to take place (Cohen and Manion, 1989: 274). Again,

Slife and Williams would argue that, whenever the pragmatic argument for this approach, it leaves the requirement for new theory that has yet to be developed. Dialectical materialism provides such an overarching theory, without the requirement that all the contradictions within the situation be immediately resolved.

The case study approach

Both Vygotsky (Vygotsky, 1978: 8) and following him, Lois Hood-Holzman, decry the absence of a dialectical materialist method (Hood-Holzman, 1996: 88). However there is a dialectical materialist perspective. Hood-Holzman makes this clear when she contrasts the interpretation of social situations by supporters of a dialectical materialist position and those who interpret similar situations from a pragmatic perspective. She sees pragmatists as uniting behaviour and meaning in one unit of action. From the dialectical materialist perspective behaviour and meaning don't unite. Rather they are poles – two contradictory elements of the same phenomenon that do not resolve in action but are better understood as activity, with understanding coming through the movement of history (ibid: 91).

In the absence of a dialectical materialist method the methods available tend to split into those associated with a behaviourist approach which abstracts reality using quantitative analysis and those that try to interpret action and meaning through small-scale research interpreting the specific (Cohen and Manion, 1989: 11 and 40). Both methods can be adopted by a researcher applying a dialectical materialist position. The key issue is the research question. In this case concept formation points to the individual in a social setting – not to the broad brush of the individual in general and the social setting in the round, but to the singular – the single individual in a specific social setting.

Michael Bassey maps the case study on a dimension of sampling versus singularity, and argues that some aspects of the case study serve to produce predictive fuzzy generalisations and other aspects produce interpretive stories (Bassey, 1999: 4). I plan to observe both behaviour and meaning and to unite them through a holistic overview of the life history of concept formation.

My research falls into the case study perspective in the sense that I observe closely the activities of a particular case – in this case of concept formation in the secondary school classroom – and to probe deeply to establish the life cycle of concept formation about reproduction in the classroom. I expect to be able to generalise to the wider population to which the instance belongs (Cohen and Manion, 1989: 124). At the heart of the case study lies a method of observation, in this case the structured situation. A major role of the observer is to minimise reactivity. My role of teacher allows me both to structure the situations and also to make invisible the role of research by providing ‘cover’.

Cohen and Manion suggest that there is a dimension to the case study approach. Highly structured approaches, for example that of Lambert et al (reported in Cohen and Manion, 1989: 137), may be linked to explicit theoretical approaches which the study is meant to prove or disprove. Other researchers, such as King, also reported in Cohen and Manion, go in without any such clear picture and are looking to the study of the case to produce grounded theory – even this, as Cohen and Manion point out, is a theoretical perspective (ibid: 141). At one pole the researcher attempts to emulate the rigour of the positivist approach from an interpretive standpoint. At the other pole researchers hope for close observation and reflection to produce grounded theory with which they can generalise to other cases.

My intention is to move along this methodological dimension as I attempt to walk through the life cycle of concept formation. The focus here will not be the

case as situation as posited by Cohen and Manion (ibid: 124) but rather the case as issue as defined by Stake (Stake 1995: 16-17). The case as a bounded system is given. It is the secondary school classroom and pupils to which I have ready access. It is not this in itself that is the focus of study. Rather it is instrumental in allowing the study of something else, an issue or generality of which this case is simply an instance. The case as issue is the process of concept formation itself. The initial and final phases will be investigated by interview and the methodology of interview will predominate, although it will still be seen as part of a case study perspective because both the interview and classroom observation will take place within structured situations filtered by a focus on the issue of concept formation.

Outline of the research

An initial task will be to define what a formal scientific concept of reproduction would be.

The initial interview will aim to establish the existing views of the child by a structured situation based on concept cards and a board. When assembled this will give the child's explanation of a life cycle involving reproduction, extended by a limited number of probes to see if more detailed concepts are held.

This understanding is confirmed by the child's narrative account.

At the opposite pole of this naturalistic account will be elements that focus on behaviour. Accounts where the human life cycle is elicited first will be contrasted with situations where the plant life cycle is elicited first. I will also look at evidence for different cognitive processes by observing behaviour.

The final interview will be similar in nature. The major task will be to apply the concept of reproduction in unfamiliar situations. Observation of manipulation will be confirmed by narrative. Plant and animal accounts will be shifted in order and contrasted.

Between the two interviews lie the classroom observations. These are again structured situations, based around classroom tasks, models and activities prepared in advance and based on my own picture of concept development in this area. However in these cases the task binds the situation much more loosely so the pole of observation is much more naturalistic, with an expectation that 'grounded theory' will arise from reflection, giving more detail about how concepts form in practice and hopefully shedding some light on the question of intersubjectivity and how, if Vygotsky is correct, concepts can form externally before moving inwards. Again the interpretive will contrast with behaviour, with a contrast between those developing the concept of human reproduction first and those attempting understanding of plant reproduction first.

Finally I will attempt to use syllabus and textbooks to analyse school knowledge and assess the extent to which the task of forming scientific concepts is central to school science.

Approach to data analysis

The framework for data analysis will be, yet again, the issue of concept formation. A basic model of male and female gametes fusing to produce a zygote will be used as a standard to assess pupil responses. Much reliance will be placed on the pupil's narrative and manipulation of sign but, again, these accounts will be contrasted with behaviour.

In the initial interviews completed concept boards and pupil narratives will be used to assess pupil knowledge. The extent to which there is a statistical difference between those who study plants first compared with those who study humans first will be assessed in order to establish if there are internal “modes of thought” that can assist or block understanding. Videos will be analysed to see if a range of strategies for establishing the concept can be identified.

The focus of study in the classroom will be the group. In each area of study a key task will be set – for example, jumbled concept cartoons to establish how the pupils jointly arrange a narrative or building a model flower to establish the extent to which technical terms are accepted and used as empty concepts. Overall I hope to establish a picture of interaction between individual, group and classroom and of the operation of intersubjectivity in the process of concept formation. Again there will be a comparison between those who study plants first and those who study humans first to establish if different cognitive processes are involved.

The final interviews will interpret the sequencing of cards and narrative by pupils to establish their ability to apply a concept of reproduction in new circumstances. I will attempt to establish through analysis of the response to probe questions scaffolded by line diagrams the pupil’s ability to link structure and function in flower structure and their ability to state the formal scientific definition of sexual reproduction in an unfamiliar situation.

The analysis of the science curriculum and texts will rest upon my understanding of formal definitions in science as being nested within superordinate structures and linked to subordinate definitions. To what extent do the texts demand a scientific concept? What Vygotsky would have seen as a mature concept?

The question of ethics

If one accepts a dialectical materialist approach then the question of ownership of research is tied to the nature of the research. To the extent that those involved were subjects of research, constructing meaning with the researcher then they can credibly claim ownership of the research and its findings.

In this case I would argue that my pupils, and to a lesser extent their parents and the school and staff are both the subjects and objects of research and my duty as researcher is one of care, which involves within itself the duty of obtaining informed consent and extending ownership by making as explicit as possible the nature of the research question and what is being asked of them. I believe that the topic of research involves specific problems and I intend to explain how I fell into this particular research question and how I dealt with the problems involved.

I intend to go into greater detail about the research instruments, data collection and analysis and resolving ethical issues in the next chapter.

Conclusion

In this chapter I have attempted to explain Vygotsky's commitment to a dialectical materialist perspective as a method of resolving the crisis of psychology. It is difficult to transmit this commitment into a particular methodological approach, but I suggest that in the intimate area of a developmental space an approach I call the 'structured situation' might bear fruit. Dialectical materialism is not itself a method, but it does suggest a shifting of perspective from objective to subjective that should provide a form of triangulation for the study. This led me in the direction of research instruments that I believe fit within the case study tradition. In the next chapter I intend to go into more detail about the research tools I developed and the practical and ethical issues that I faced in carrying out the research.

Chapter 5

The study as case study

Introduction

In chapter 4 I attempted to walk my way through from Vygotsky's concern with a theory of mind to his concerns about methodology. These were linked by his view of a crisis of psychology caused by the inability of psychology to overcome the contradiction between the human as agent and the human as object. In Vygotsky's view this contradiction could be overcome, at least in principle, by an understanding of dialectical materialism. I suggested that a method, which I call the 'structured situation' could be used to allow the study of meaning and that a dialectical materialist approach would allow different perspectives on a situation that would serve as a form of triangulation. I then outlined the life cycle of my own study, suggesting that the approach was similar to the case study approach in its focus on the individual case and on abstracting meaning.

In this chapter I want to contrast my approach to the case study as the study of a particular issue with the study of the case as an instance. This will suggest the extent to which the study can be generalised, allow me to go into more detail about the environment in which the case study was carried out, explain the ethical position in more detail and also outline some elements of a 'chapter of accidents' that constrained the study and restricted to some extent the firmness of the conclusions that I could draw. In considering the generalisability of the case study as issue an important aspect should be what Schofield considers the 'life cycle' of the issue. He views the quantitative

study as often resembling a snapshot, while qualitative studies can be seen as movies, following the development of an issue over time (Schofield, 1993:105). I will expect to follow the development of the concept of sexual reproduction through out its life cycle – from initial perception to mature concept. In general my initial expectation is of the sort of general process seen in figure 3.2, with the specific elements more clearly expressed in figure 3.3. My expectation would be that the internal coherence of the narrative would provide a form of triangulation, showing the extent of movement through a developmental space.

The case study as situation

Insofar as the case study can be regarded as the study of the instance, the instance in this case clearly has a dual nature. On the one hand it is the study of an issue – the life cycle of concept formation. However, it is also, on the other hand, the study of concept formation in a particular situation – the situation of a secondary science classroom. This clearly has implications at all sorts of levels and I will want to look at some of them in more detail when I analyse the outcome of the research. For example, Vygotsky saw the formal 'scientific' approach in schools and the explicit, self-reflexive nature of the activity as advanced forms of thought allowing metacognition. Dillenbourg defines metacognition as the process of becoming aware of one's own knowledge or one's own cognitive processes (quoted in Puntambekar and du Boulay, 1999: 245). Brown defines metacognition as reflection leading to a strategic view of one's work guided by a clear view of its goals (quoted in Black, 1999: 126).

To what extent is it the case that school knowledge has the character and status assigned to it by Vygotsky? Lave and Wenger saw the concept as firmly embedded in the social situation (Lave and Wenger, 1999: 23). This would indicate that school concepts are a special form of knowledge distinct from those in the outside world – an idea to some extent endorsed by the early work of Susan Carey (Carey, 1989: 107). However at this particular stage I want to look at the situation as a sample. To what extent is it

representative of a more general population? Traditionally the positivist approach would have seen this as simply a matter of statistics, a view justified by the assumption that the elements under investigation were variables rather than elements of meaning. Schofield suggests a number of approaches that would allow the researcher to generalise from the case (Schofield, 1993: 98-105). The approach that seems most valid is the study of the typical. Typicality taken to extremes would lead to its own contradiction – a situation that was average in every way would clearly be untypical. However by improving the ‘fit’ of a situation the researcher would be able to combine the nature of the situation with ‘thick’ description to make more informed decisions about the generalisability of the situation (ibid, 99). The pupils are within the normal range of the secondary school population in the sense that they have been assessed as covering the standard ability band within that group and a range of social classes (with the skew, reported before, that most able pupils and, to an extent, higher social classes, are not represented). The activity the pupils are undertaking is, at least in its rough outlines, common to all pupils subject to the common science curriculum.

The not quite typical

An important aspect of the study, linked to questions about generalisability later, is to make explicit the extent to which this study of the typical is a study of the not quite typical.

The fact that I am a teacher in full time work effectively constrains the area of my researches to my place of work, a small, rural, co-educational secondary school with an enrolment of 430. (One alternative was available, as I also teach adults in a night class once a week, but I believed that data about concept formation would be more generalisable from a study of children).

Constraints on an investigation would be presented by pupils studying for key stage three or four examinations. Effectively this restricted me to

Northern Ireland years eight and nine (in Britain this would be years seven and eight). Plant reproduction, the topic around which I had decided to base my investigation, was on the year eight programme of study and there were fewer special needs pupils in my year eight group – the year nine group might have presented problems of design and data analysis later because of a number of pupils with specific learning difficulties needing some level of individual support. With the year eight groups there was some fear of an induction effect – that as newcomers they would have a different approach to teaching and learning to the old hands who made up the bulk of the school population, but as the bulk of the research would take place in the spring and summer terms, this seemed to be a minor consideration.

There are about ninety pupils in year eight, of whom 22 are taught directly by me. The pupils have been through an 11+ transfer procedure in which the vast majority had scored below Grammar school entry level. A top stream is selected on the basis of reports from their primary school, induction tests and transfer tests. The other groups are considered to be of mixed ability.

Initially I hoped that this would be, in a rather miniature way, a multi-site case study with interviews and observations across the four first-year classes that would tend to compensate for aspects of the study such as different teaching styles but, for reasons that I explain below, I had to restrict the range of the final study. This had the effect, which I again explain later in more detail, of increasing the reactivity of the study.

The research relationship

Much of the conduct of the research, and to an even greater extent my approach to the ethical questions that arose, came from my view of the research relationship with my pupils. The Vygotskian perspective suggested to me a dimension/contradiction between the pupil as agent and the pupil as object of research. It seemed to me, on reflection, that in the overall production of research the pupil, and to a certain extent the

parents/guardians and staff of the school, were to a certain extent the objects of research, in that we did not have a common goal of research –the goal was my intellectual invention – rather I had their willing and knowing consent to co-operate in the research. My responsibility lay with a strategy to develop and present the outcomes of the research process in such a way as to maximise the element of common ownership. Part of that strategy was to ensure that the pupils, parents and staff had a right to access the results of the research involving them and from that perspective I have decided to make available the final thesis in the school and inform the participants of its availability in line with BERA guidelines (BERA, 1992:2).

Consent and support, from parents and pupils and from the school principal, was rather easily obtained by letters requesting support and, in the case of the pupils and parents, of patient follow-up over a period of weeks (see appendix A.1). What was left then was a duty of care in my role of teacher and researcher.

This duty existed at a number of levels. I had to ensure that variations in the curriculum were such that I did not know in advance that pupils would be disadvantaged by being taught one scheme rather than another. I had to preserve the anonymity of the pupils, as far as was practical, by giving the school an invented name and coding each of the pupils with a research name that did not provide a clue to their actual name – although I did preserve the distinction between male and female – often seen as a factor in differentiation in educational studies.

The circumstances of interview were the focus of detailed discussion with the principal in line with BERA guidelines (BERA, 1992:2). They had to meet with the provisions of the school's child protection policy (see appendix A. 2) that discouraged private interviews between pupils and staff in isolation. Insofar as was practicable two staff should be present at interview and, where this was not possible, doors should be left open to create a public interview space. Elements of this policy produced difficulty, as the point of the interview was that it would be private. After some

discussion we agreed an interview setup which met the requirements of the policy (see appendix A.3). The children were interviewed in the science preparation room. The technician was present in the background but had no active role in the interviews. The interviews were videotaped and children awaiting interview were within sight in the foyer but not within hearing range. Children who finished interview were allowed to read in the classroom next door. The initial interviews were completed in two days to reduce reactivity. It seemed evident to me that the longer the interviews went on the more they would be the subject of discussion amongst the pupils and the more likely this would be to change the responses of the pupils interviewed later.

There was a further level of care that needs discussing. I think I need to explain how a middle-aged man came to be interviewing young children about sexual reproduction. I have explained in the introduction how the initial impulse for the research came from a lesson on plant reproduction. I began to carry out pilot work and used the same topic as framework. It was only when I began to design the final study and looked at the structure of the knowledge required that I realised that the science model, when generalised to cover the general outcome of fertilisation and the formation of a new individual, covered both plant and animal reproduction. Even then there was a 'quality of easiness' arising from many years of teaching the topic that hid the rather more difficult position of the researcher. In the event I gambled that the distance from the topic, the trappings of the science department and familiarity with myself reduced embarrassment to a low level.

I prepared to cut short interviews in the case of difficulty and had a supplementary probe about embarrassment for pupils who had long pauses or difficulty in answering. In the event only one pupil claimed embarrassment with the task of explaining human reproduction – he was subsequently unable to explain the process of plant reproduction. Another pupil became confused about the sequence of events in human reproduction but insisted on being interviewed again the next day and was then able to

explain in detail about human reproduction and insist that they had known the details all along!

I do not believe that the nature of the topic inhibited pupil response – in fact I was rather taken aback by the ease with which the majority of pupils discussed the issue. Reflection did however alert me to the sensitivity of the topic and suggested that this may have constrained and structured the science curriculum and science pedagogy in the past. I will return to this issue when I consider the nature of science in the secondary school environment.

Obstacles to the investigation

The preparatory stages of the investigation went well. I issued and collected letters establishing parental permission (see appendix A.1) and negotiated the support of the principal, the technician and the other science teachers. I began the investigation and immediately ran into trouble. I had planned to videotape all the initial interviews and had been promised the loan of a library board camera. We ran into trouble with a camera fault and, when the technician and I struggled with it, the board called and asked for it back. We started the interviews with just audio and notes, obtained another camera from the teachers centre – but they asked for it back after 2 days. We finally obtained a loan of a camera from the Partially Hearing Unit attached to the school but this had a number of drawbacks. It was large and obtrusive and the battery was permanently flat so it had to be connected to an electrical outlet to function and it was not available at all times. We were able to overcome these difficulties and carry out the interviews, but I had also arranged with the technician that we would run a series of preparatory tapes in the science classrooms simply to acclimatise the children to the presence of the camera. Because of a heavy workload on both myself and the technician we frequently forgot and, when we remembered, the camera was not present in the science block. However we were able to carry out six video ‘dry runs’ and a similar number of audio tests. An interesting

observation at this point was that the children appeared to adjust very quickly to the camera but never seemed to acclimatise completely to the audio equipment. My speculation would be that they are familiar with video cameras and with the concept of 'reality TV' but that audiotaping is now relatively uncommon.

Finally I fell ill and lost a week. When I returned disaster had struck. An inspection of the school had been announced. Really it became impossible to ask any other members of staff for co-operation as they prepared for the inspection and my own time was severely restricted. I completed the first set of the initial interviews and prepared the teaching and interview materials I would use later, but lost April and most of May. I could see that my design for the study would have to be amended, and as a precaution I decided to interview all the members of my own class. My feeling was that the size of the pupil sample was likely to get smaller as we approached the end of the school year and a number of families took early holidays. I felt it would be wise to gather information in as great a depth and detail as the situation afforded.

Following the inspection I received a great deal of support from the principal. It was agreed that I could retain all my non-cover classes to complete the study, but to make full use of this I had to carry out the "classroom observation" just on my own time. I therefore had to take my own pupils and, to retain a comparative element, I split the class group of 20 into two groups of 10, one of which, group A, would begin with a study of human reproduction and then study plants and the other, group B, that would reverse the path of study, studying plant reproduction followed by human reproduction. This was to follow my initial model of a developmental space in figure 3.3. I planned to contrast the two groups to see if the order in which the topics were approached had an effect on learning. I was not able to choose the membership of the groups. That was determined by who was available at the fixed point on the timetable. The

class groups had been amalgamated for other subjects at that time, so effectively the choice of which pupil went into which group was random. I looked at the lists for the two groups very carefully and I was unable to see any particular difference in background or ability that would affect their performance as a group.

The change from class group to experimental group had a number of effects. The pupils showed a very clear reactivity. It was not the same as a real lesson and they did not appear to be as committed to class work as in normal science lessons. Secondly the sample size was smaller and it would be more difficult to generalise from it. Thirdly everything had moved further back in the school year and this had an impact both on attention in the classroom and on the final interviews. These were so late in the school year that I began to run into the problem of children going on holiday early and eventually had to take whoever was present on those days. As I tried to stick to the original interview schedule I ended up with rather a mixture of children who had simply been interviewed and those who had been interviewed and taken part of the classroom study (and a few who came along anyway).

I did however have a few pieces of luck. The school obtained a modern compact digital camera which was put at my disposal. I came across an earlier tape of pupils in one of the other classes which the technician had recorded in my absence and which proved useful comparative material. Finally it turned out that the alteration between plant first and human first, which I had fallen into almost by accident, showed a quite significant difference between the two groups in the classroom observation element.

Conclusion

As it was both the instance and the issue of the case acted to constrain the conduct of the research. The instance dictated the sort of sample that was available and the extent to which it was available as a research subject. Accidental elements deformed and constrained the data available. The case

as issue presented some problems, especially of an ethical nature in the sense that there are obvious difficulties about discussing human reproduction with children that become invisible from within the everyday world of 'doing' reproduction in the science lab. These problems led me to reflect on the way in which the science curriculum, and commonplace science pedagogy, responded to the issue of reproduction. I began to suspect that one factor influencing the curriculum was to make the issue of reproduction 'safe' for adults and children.

In the next chapter I want to focus in more detail on the nature of the initial interviews, the data collected and the ways in which I interpreted it and the outcomes in terms of the conceptions about plant and animal reproduction held by the children at the start of the study of concept formation.

Chapter six

‘Structured situations’ part I Interviews and interpretation

Introduction

In chapter six I explain my perspective in approaching the initial interviews as ‘structured situations’. The structuring of a developmental space in relation to reproduction and the sort of outcomes that I expected are laid out. The conduct of the interviews is explained and the outcomes are set out in some detail and represented in graphical form and I then interpret the meaning of these results and revisit some elements of the literature to see the extent to which my interpretation can be supported. In some aspects the results were as expected. In others there is an element of surprise and it is on the interpretation of these results that I focus, arguing that my interpretation gains validity from the movement between interpretive and behavioural elements of the study.

Structured situations

The initial interviews can be seen as structured situations in that a structure is provided by concept cards and boards that can be used by the pupil to construct

meaning. The interview element essentially consists of a series of probes to elicit meaning from the pupil with further extension probes to see if the pupil can extend the meaning that they have already ascribed to the situation.

The situation contains two forms of inherent meaning. The first, summing up the goal of schooling and resting on many of the assumptions of science, is the scientific model of reproduction. A connotative set of associations can be reduced to the model; male gamete, then female gamete, fertilisation and the formation of a zygote or new organism. The second form of inherent meaning, through which the observations of the researcher are made, is the concept of scaffolding and the zone of proximal development. The items that provide structure to the situation can be regarded as a form of scaffolding. The structure that is potentially present in the situation can only be elicited if the concept of sexual reproduction is within the zone of proximal development. I can be reasonably confident that some aspects should be available to the pupils given that a simplified form of the life cycle is taught at primary school. Driver et al indicate that I can expect a number of responses from children that can be put in order in the sense of going from the simple to the complex; from the idea of growth to the concept of mating, from mating to the idea of the womb as garden and the sperm as seed, from there to the concept of fertilisation and hence to the full science concept of gamete and zygote ((Driver et al 1994: 49).

So the first outcome of the initial interviews is a type of structure; the formal science structure, an alternative structuring or unstructured arrangements of the cards. The extent to which this represents meaning will be supported by an accompanying narrative. I will also be able to compare the pupil's ability to understand reproduction in plants and humans by comparing the numbers able to provide coherent explanation in each case, and I will be able to obtain some evidence of internal mental process by contrasting the time taken to complete the life cycle in each case and the effect of alternating the first interview on the

human life cycle with a group who attempted the plant life cycle first. Other evidence for internal mental events will be achieved by looking for strategies in handling the cards – my belief is that the more structured the internal activity the less the cards will be manipulated.

The various activities can be represented along a dimension of meaning as:

Meaning

- Explanation of life cycle
- Arrangement of life cycle
- Comparing of plant and human results
- Contrasting of plant and human results
- Gesture analysis

Behaviour

It is expected that, to the extent that the behavioural pole of the analysis supports the pole of meaning, a form of internal triangulation of the study will exist.

The interview setup

The interviews were carried out in the science store, organised to meet both the privacy requirements of individual interview and the child protection policy of the school (see appendix A.3). Two concept boards were supplied, one for plants and the other for humans and cards for insertion into the boxes (appendix B). The boards were organised in dual circles with a central square given (exploding pod for plant, foetus for the human). Copies of the boards were held

on individual interview record sheets which were filled in for each pupil (see appendix B.7). All but the first six interviews were videotaped. All interviews were audiotaped and the time taken to complete the life cycles recorded.

The children were asked to set out the life cycle, to explain the life cycle, to identify the new life and to indicate where the new life came from (The interview schedule is printed on the record sheets). Alternate pupils either started first with the human life cycle or with the plant life cycle. The intention was to establish the pupils existing concepts, to see what role manipulation of sign had in developing or confirming concepts and to see if there was support for the idea that concept formation was aided by a social intelligence which would aid concept development with the human life cycle, or a natural history intelligence that would aid the plant cycle.

Overview of the initial interviews

All 41 pupils in the initial interview showed an interest in, and enthusiasm for, the tasks they were asked to carry out, often showing a high degree of emotion and frequently anxiety. As the study progressed I began to feel that this was a highly significant observation and I will explain why later in the study. The vast majority of the children (35) had some difficulty with the task of construction of a life cycle using the cards, even though life cycles are a major element of the primary science curriculum. A persistent tendency was the tendency to lay out all the cards in a single cycle, ignoring the information and structure contained within the board. This dominated the attempts of 15 pupils who persisted to the end of the task, and was present to some extent in most of the other pupils who corrected the initial single-cycle tendency.

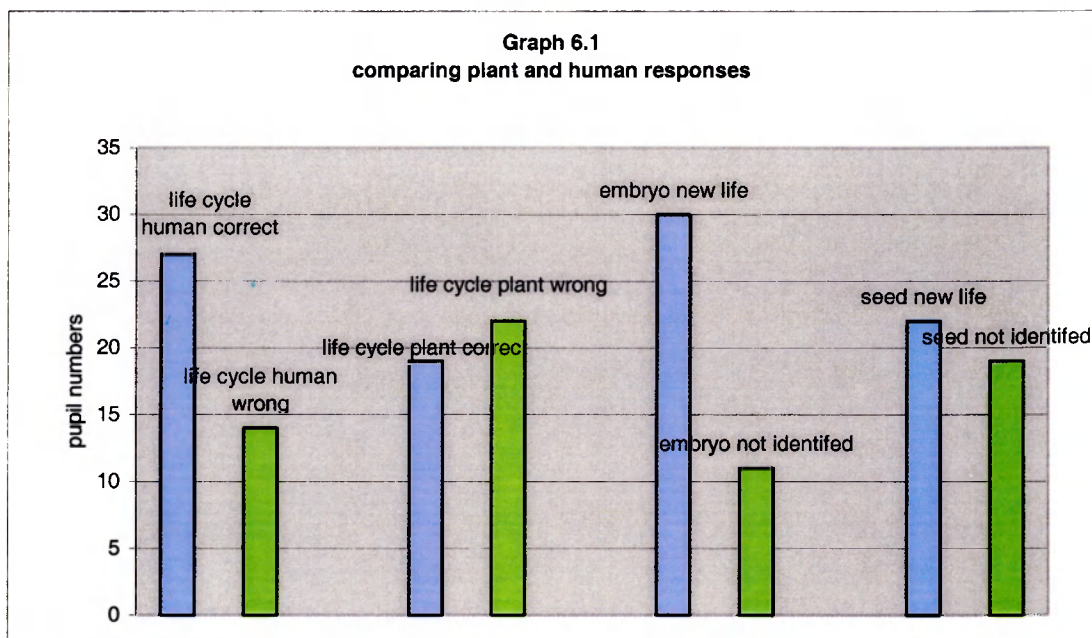
27 pupils (66%) succeeded in constructing a human life cycle using the cards.

Only 19 pupils (46%) succeeded in constructing correct plant life cycles. All the children who successfully constructed life cycles were able to explain in narrative the life cycle process, but only two boys who failed to construct a

coherent life cycle went on to give a correct narrative. 30 pupils (73%) correctly identified the embryo as 'new life'. 22 pupils (54%) were able to correctly identify the seed as the source of new life.

None of the pupils indicated a full understanding of the science model for reproduction. Some part of this failure may be due to embarrassment, but given that the failure was even greater with plants this is unlikely to be the main explanation. Some of the embarrassment that was evident was, it appeared to me, due to an everyday understanding that copulation was involved, but where pupils were willing to answer the concepts they advanced were in line with Driver (Driver et al 1994: 48) and with Susan Carey (ibid) – that is that the baby grows in the mother's tummy. One pupil claimed to be unable to answer any questions about the human life cycle because of embarrassment, but was equally unable to answer questions about plant reproduction, where one would imagine embarrassment would not be an issue. Another pupil, who was unable to answer questions insisted on being re-interviewed the next day, when they were able to give fairly full answers. In this case the embarrassment of not knowing was greater than the embarrassment of knowing!

The comparative element of the initial interviews



As is shown in graph 6.1, 15 of the pupils persisted in trying to construct the human life cycle by arranging the cards in a single cycle. 13 pupils were unable to complete a coherent life cycle and 2 eventually succeeded. Of the 26 pupils who used the dual cycle structure of the concept boards 4 pupils were unable to complete a coherent life cycle and 22 eventually succeeded. 18 pupils attempted to construct the plant life cycle by arranging the cards in a single cycle. 13 pupils were unable to complete a coherent life cycle and 5 eventually succeeded. Of the 23 pupils who used the dual cycle structure of the plant concept boards 9 pupils were unable to complete a coherent life cycle and 14 eventually succeeded.

Contrasting plant and human

Of the 27 pupils who correctly completed the human life cycle 14 (52%) attempted the human life cycle first and 13 (48%) attempted the plant life cycle

first. Of the 19 pupils who succeeded in constructing a plant life cycle 12 (63%) attempted the human life cycle first and 7 (37%) attempted the plant life cycle first.

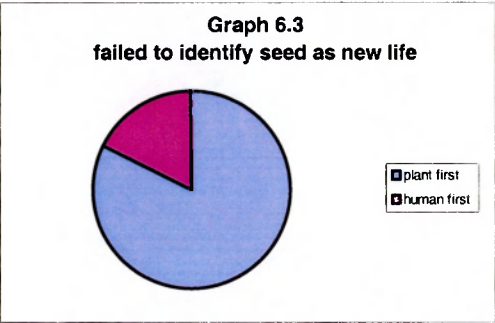
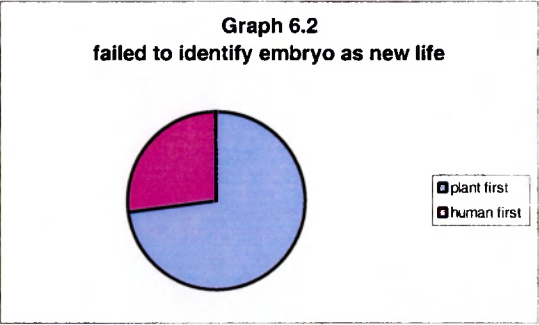
Of the 20 pupils who attempted the human life cycle first 14 (70%) got the human life cycle correct and 12 (60%) went on to get the plant cycle correct.

Of the 21 pupils who attempted the plant life cycle first 7 (33%) got the plant life cycle correct and 12 (57%) went on to get the human cycle correct.

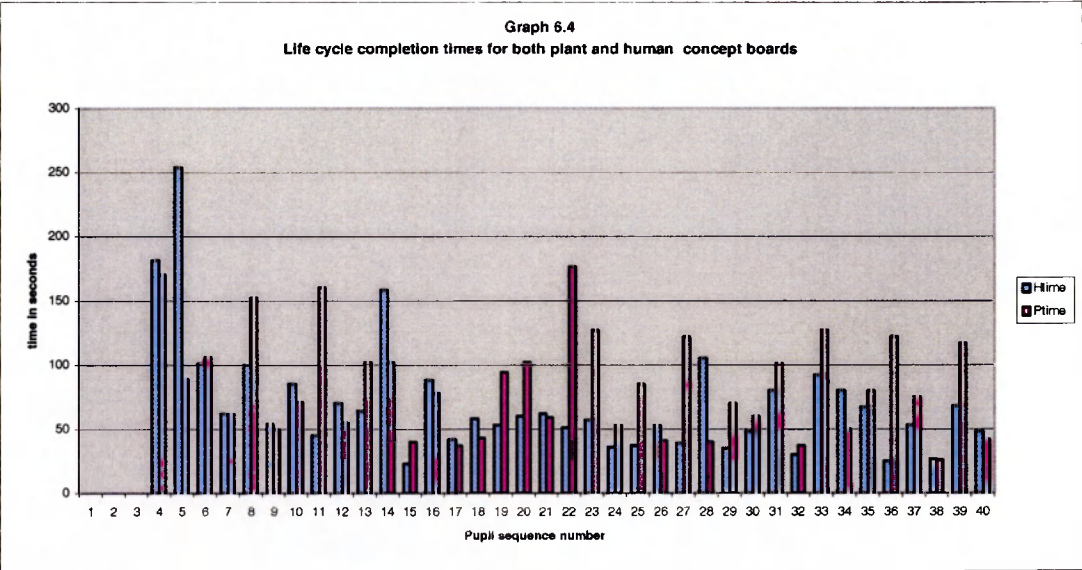
There was a small overall faster response from the pupils who attempted the human life cycle, although this was not always connected to an accurate response.

11 pupils (27%) were unable to identify the human foetus as new life. 8 of these attempted plant first (graph 6.2). This suggests that the plant task in some way blocks thinking about human reproduction.

17 Pupils (41%) were unable to identify the seed as new life. 14 of these attempted plant first (graph 6.3). This suggests a greater difficulty in thinking about plant reproduction from a biological perspective.



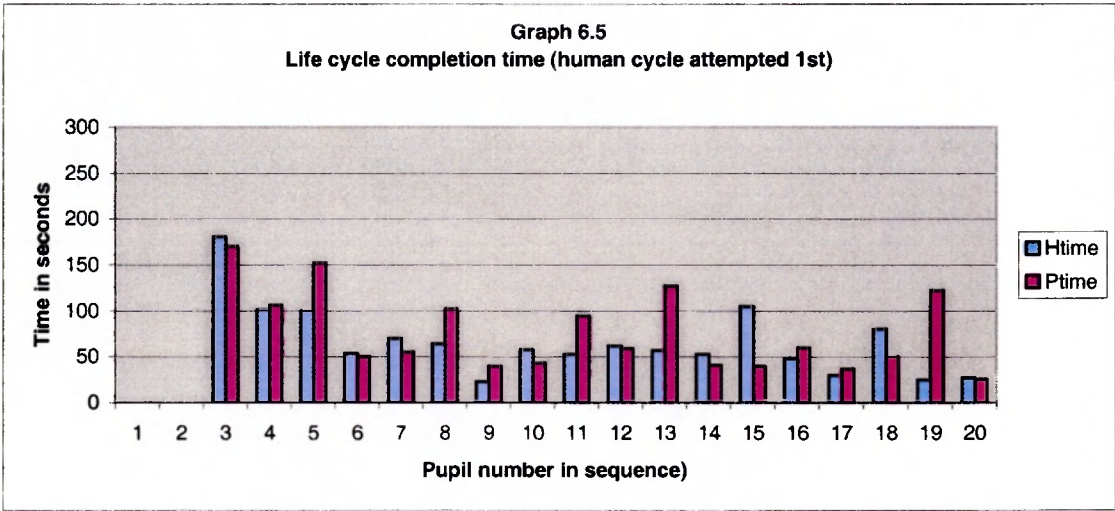
A comparison of completion times proved useful. The following graph (graph 6.4) shows results for both human and plant concept boards, following the sequence in which they were carried out



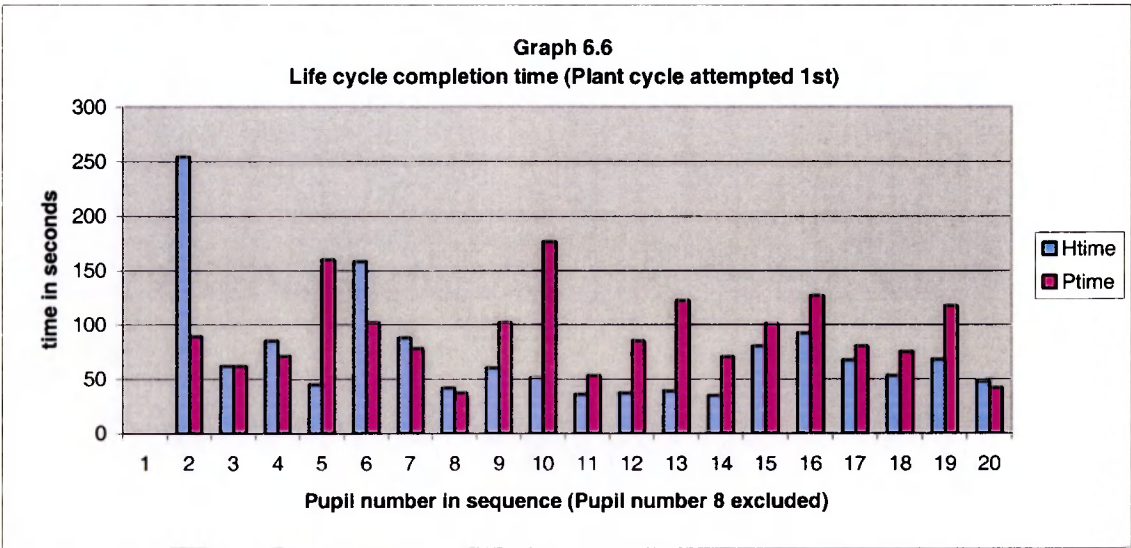
Graph 6.4 indicates that human life cycles were completed faster. Average time for completion of a human life cycle was 68 seconds and average time for completing a plant life cycle was 82 seconds. (I excluded candidate 5 from the

average on the ground that completion times for this candidate were twice the next slowest candidate).

This might suggest simply greater ease and familiarity with the concept of the human life cycle, so I took into account the order in which the boards were completed as follows:



In graph 6.5 the average completion times were 66 seconds for the human life cycle and 76 seconds for the plant life cycle.



In graph 6.6 the average completion times were 74 seconds for the human life cycle and 92 seconds for the plant life cycle.

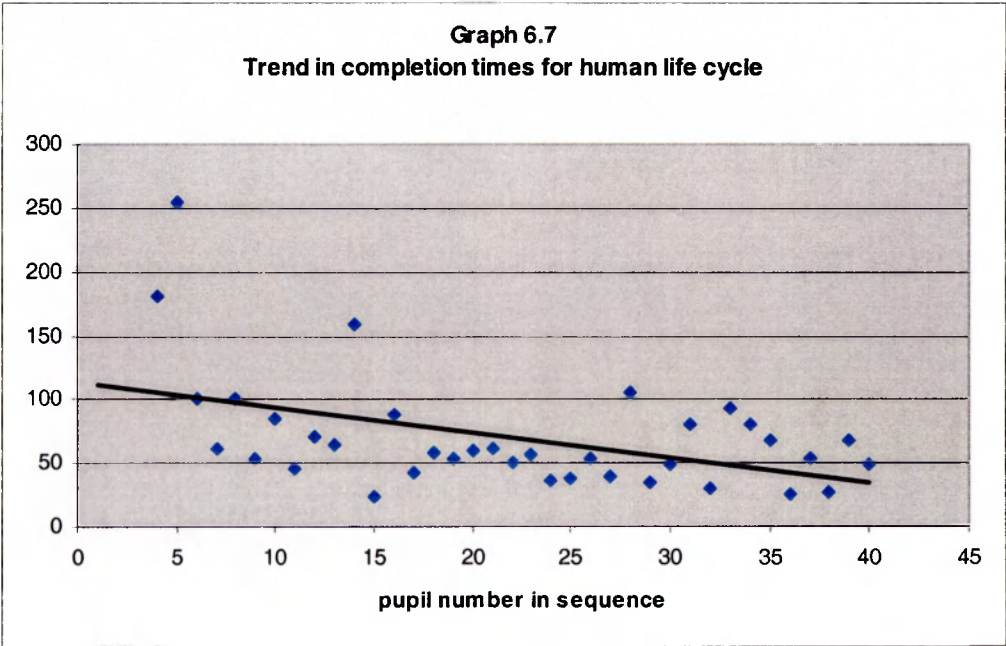
In summary the results are as follows:

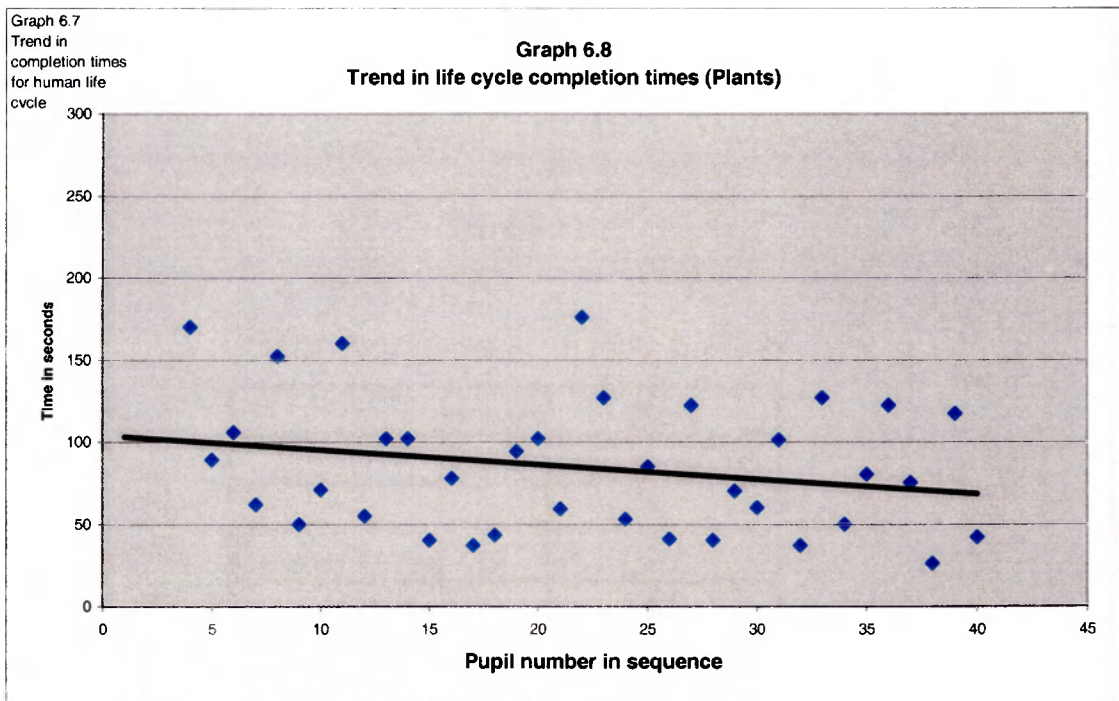
Table 6.1

Concept board completion times (seconds)

	Human	Plant
	time	time
overall	68	82
human cycle 1st	66	76.
plant cycle 1st	74	92.

I went on to establish trend lines for completion times. The results are as follows:





Graphs 6.7 and 6.8 appear to indicate that there is a level of reactivity arising from pupil chat between those who have completed the interviews and those not yet called. It does not appear strong enough to falsify the data. However it is a stronger trend for the human life cycle, suggesting relative unfamiliarity with the plant life cycle.

Interpretation

A major surprise of the interviews was the role of the single life cycle, learnt as part of the primary curriculum. The single cycle life cycle does not appear to be a mature concept and fits with the Vygotskian idea of a complex – it should disintegrate when challenged (Vygotsky, 1971: 61). In fact it proved remarkably resistant to change, fitting in with Carey's evidence of the persistence of spontaneous concepts (Carey 1989: 106) and Osborne's evidence

of children's 'minitheories' which were resistant to change (Osborne and Freyberg, 1985: 132) but, in this case the resistant mental structures are not spontaneous concepts arising from everyday experience but appear to fit more easily with Engeström's idea of encapsulation – special mental structures formed in the process of schooling (Engeström, 1996: 155) and Hedegaard's view that school knowledge is mostly empirical and, because it lacks a theoretical understanding, is not incorporated with existing knowledge (Hedegaard, 1996: 180). It thus appeared to serve a dual function, for some pupils serving as the base line of a ZPD that they could travel along to form a more developed concept of reproduction, for others acting as a barrier preventing further development of the concept.

The fact that pupils tended towards a faster response in constructing the human life cycle and did rather better at it would hardly come as a surprise. What was surprising was that the order in which the life cycle was attempted seemed to make a significant difference. Beginning with attempts to resolve the plant life cycle tended to produce a poorer response to both plant and animal life cycles and to the detail in which pupils could respond. In my opinion this finding fits in with the findings in Driver et al that plants are regarded in a different way from other living things (Driver et al, 1994:19) and provides grounds for suggesting that different thought processes about different categories may block each other in line with Carey's argument that different modes of thought are involved (Carey, 1996: 187), and in line with Mithin's idea that different intelligences assemble different aspects of reality within the brain (Mithin, 1996: 78) and with Carey's idea that a spontaneous 'folkbiology' is not innate (Carey, 1996: 210). In fact she suggests that biological elements of human life would be more easily assimilated because the pupils would already operate a developed 'folkpsychology' in which these elements would be accommodated.

A study of gesture led me to identify a number of approaches adopted by the children that may be indicators of the maturity of internal mental structures and thus of the individuals position on the zone of proximal development – those with fully internalised and developed concepts would have little need for extensive external gesture.

Children were observed to use the cards in a number of ways:

- Reflection involved pauses with very little manipulation of the cards. Often one card was held on the lips or near the face.
- Laydown meant that the cards were organised at one side of the board and then transferred to the board.
- Restructuring meant that the cards were laid out on the board on some rough order and then moved back and forward until the pupil was satisfied.
- Jumble meant that the cards were moved back and forward apparently randomly, often with jerky 'hunting' movements.

I believe however that there is too great a distance between the behaviour and my speculation about its meaning. A study of gesture would involve a more experimental setup rather than an interpretive one. However for the main findings in this section I believe that a form of triangulation does exist in that the interpretive element is supported by the more objective analysis of percentage success at various stages and by the comparison of completion times in tasks differing only in the sequence in which they are carried out.

The trend lines in graphs 6.7 and 6.8 are interesting. They suggest a level of reactivity in that those interviewed later in the schedule had some knowledge of what the interviews are about. I saw the two pupils who gave correct narratives

and incorrect concept board structures as being strong examples of reactivity. It may be that they had questioned pupils earlier in the interview list and, knowing 'the answer' had not bothered to engage with the concept boards. The graphs tend to suggest that this reactivity did not make a significant difference to pupil responses and, interestingly, that responses were less affected where plants were involved, suggesting that information picked up was less easily understood by the pupil.

Conclusion

Certain outcomes from the study were as expected. It is not surprising that the single-cycle life cycle taught in primary school should predominate or that pupils lack full understanding of the scientific model of sexual reproduction. It is surprising that the primary understanding should, in a number of pupils, act as a barrier to further understanding, that ways of thinking about plant and animal reproduction should appear so different and that it appears to be so difficult to move from a 'plant reproduction' mode of thinking to a 'human reproduction' mode and relatively easy to move in the other direction. The 'structured situation' seems a robust mode of enquiry and should prove effective in classroom observation.

Chapter 7

‘Structured situations’ part II: Classroom observation

Introduction

I saw the classroom observations as yet another example of ‘structured situations’. The structure is constrained as an issue in that, as before, I will be providing visual cues, activities and instructions out of which I hope the children will elicit meanings. As before I hope to be able to establish those meanings through the children’s statements and by examining the written records that they provide. I will need to bear in mind also that the situation is structured as an environment in that it will tend to produce the responses typical of a secondary classroom. The search for meaning will only partly focus on the individual. There is an expectation that the new concepts will begin life as intersubjective ideas and, as they gain in formal meaning externally, they will also assimilate internally as idiosyncratic, individual representations of the science concepts involved, so part of the outcome will be my interpretation of observations of pupils interacting in classroom groups.

Structured situations

The classroom observations are structured situations comparable to the interviews in that they involve materials that can be assembled by the pupil to give meaning. They differ from the interviews in that:

- The materials and instructions have a looser connection to the eventual meaning.
- The conceptual space is much larger and broader.
- The numbers involved are greater.
- The social situation is much more complex, with movement between the teacher, the class, the group and the individual.
- In the interviews it was assumed, from their primary history, that most pupils would hold at some level the concepts I was trying to elicit in the interview. In the classroom observations the starting point was the assumption, based on interview, that many of the pupils did not hold more detailed concepts about reproduction, at least in terms of a mature scientific concept.

An assumption was that the meaning will emerge in some way from the group. This in some way involved the concept of intersubjectivity and one of the purposes of the observation was to theorize the process through which the intersubjective concept emerged from social activity.

Intersubjectivity

Initial ideas about how this might happen can be found by looking at the work of Piaget and Vygotsky. Both had a concept of intersubjectivity as the sharing of concepts between individuals (Rogoff, 1999: 80) but for Piaget the concept existed first in the individual and was then shared in discussion amongst equals. For Vygotsky the concept existed in the culture and was

internalised through common practice which depended on the tension between the child and the more experienced other (ibid).

Piaget saw the learner as being in solitary interaction with nature. Concepts would form through this interaction, with greater abstraction becoming possible as the child matures (Piaget and Inhelder, 1973: 13-19). Social debate would therefore be an exchange of information about already existing concepts. The process by which these private concepts become public and intersubjective is an outcome of decentering by the individual, who is then able to shift perspective to examine the other's view (ibid).

The perspective for Vygotsky was in some senses the opposite of that of Piaget. The child did not interact directly with nature but through the mediation of the word and sign provided by human culture (Vygotsky, 1971: 44). The meaning already existed in some way intersubjectively before it was adopted by the child. The focus of attention was the mechanism by which this intersubjective meaning became internalised within the individual pupil as a personal, idiosyncratic meaning. It would tend not to occur in peer interaction unless one of the individuals had a greater level of skill (Rogoff, 1999: 77). A contrasting argument from Piaget suggests that the greater authority of the adult can suppress thinking skills in the child (ibid: 78).

I see Vygotsky's idea of heaps, complexes and pseudo-concepts as being extremely useful in attempting to imagine the mechanism of concept formation within a group. It suggests that the individual pupil will be extremely tolerant of loose associations and groupings and will await the emergence of more detailed links and associations allowing the development of the detailed concept. The model of a developmental space that I advance suggests that the word of representing the new concept and the hints about meaning contained in language structure and in the social situation will be rapidly adopted. The model of developmental space also indicates how the goal of the full science concept might be arrived at, but is less clear about the factors that might inhibit the emergence of the concept.

My initial expectation was of a debate and turn taking in which the word and potential structures of meaning represented by the materials provided are advanced by different pupils until a consensus is arrived at.

As with the interview, I will be able to take a dialectical materialist position. I will be able to make some assessment of the meaning arrived at and the extent of that meaning. I will be able to estimate the frequency with which members of the groups arrive at meaning, compare these frequencies for tasks involving plants and humans and contrast outcomes for humans and plants. By reflecting on the observations I expect to produce grounded theory about the role of intersubjectivity in concept formation and the role of the group in the classroom situation.

The classroom setup

As I have indicated earlier, my experience during the pilot was that it was virtually impossible to observe and teach, so I decided to rely almost entirely on video and audio recording, with some support from brief notes, in the knowledge that I was throwing away a great deal of data in exchange for the freedom to return to the same details over and over again.

My intention had been to introduce video cameras without comment. I had mentioned them when obtaining permission for the study from parents and children and I had arranged a series of six trials when the technician went around the class with the camera and a further three trials with the camera on in fixed positions. The records of these trials were not kept, but I did view them to get a feel for the data and to establish the best points for fixed cameras and the quality of sound. In the event I collected sound from both the audiocassettes and cameras, but the camera sound turned out to be of much better quality, although the reverse had been the case in the interviews.

My difficulty was that I now had to change the structure of the study from the observation of everyday classroom activity to half-class sets. I had to explain the change and therefore draw attention to the use of cameras and increase pupil awareness and self-consciousness.

I explained the change as due to the shortage of time, but that the study would consist of material on the year eight science syllabus and they would be examined about the content of the course at the end of the year with the rest of the years work. I explained that the focus of the research would be the use of new materials and teaching methods.

General instructions were that they must work in groups, that each member of the group should give an opinion of the work as they went along and that they should at the end produce their own individual reports for each activity. This procedure was explained at the beginning of each lesson.

In the course of the classroom activity several new ethical issues arose. One was the level of misdirection. I had given the impression to the pupils that the focus of the research was the materials when in fact they themselves were the focus. I had in my introduction reminded the pupils of the voluntary nature of the activity and this was taken by one pupil, Matt, as indicating that he could leave in the middle of a lesson and go to a sing-song. My response was to indicate that he could withdraw from the activity but not from the classroom, as I had been assigned as the teacher supervising him. The effect was rather to erode the status of the research as voluntary. Finally I broke confidentiality to discuss the behaviour of one pupil with the Special Needs co-ordinator. In this case the pupil was being assessed for ADHD (Attention Deficit Hyperactivity syndrome) and I am convinced that I was acting in the pupil's best interests.

The layout of the recording apparatus is shown in appendix C.1.

Making sense of the recordings proved very difficult. I worked through the videos looking for some overview with no success. I then attempted to focus in on individuals, one at a time, and observe in frames of one minute at a time. I observed plenty of behaviour, but achieved very little in the way of understanding meaning.

I got very badly stuck at this point and analysis was held up for some time. Finally came a breakthrough. My insight was to work backwards from the outcome of the activity, which I labelled task completion because for the majority of the pupils it involved copying from others rather than any active construction of concepts. I was then able to focus on the division of labour in the processes leading to task completion, with a minority of pupils actively working and the other members of the group onlookers involved in social activities and that in turn led me to look at initial negotiation of roles and the contrast between implicit and explicit aspects of the task – the explicit being what had been formally set as the activity and the implicit what actually engaged the attention of those involved.

I decided to narrow down my observation further, by concentrating on 2 workgroups. One, in the A class, had started by studying the human life cycle and another in the B class who started with the plant lifecycle. I decided not to select the typical, a way suggested by Schofield for increasing the generalisability of research (Schofield, 1993: 99), but to look at groups who were somewhat more likely to resist classroom discipline, as my intuition was that there were also issues of motivation, attention and goal to look at.

Group A's schedule is shown below:

Lesson 1	human lifecycle	Lifecycle story
		Hidden story – the sex organs
		and intercourse
		Hidden story – fertilisation

Lesson 2	Build a flower	Use of empty concepts
Lesson 3	Flower dissections	Linkage of empty concepts Microscopic view of pollen and ovule
Lesson 4	Flower story	Plant life cycle Hidden story – Bee trip and pollen Hidden story – pollination and fertilisation

Group B's schedule was:

Lesson 1	Build a flower	Use of empty concepts
Lesson 2	Flower dissections	Linkage of empty concepts Microscopic view of pollen and ovule
Lesson 3	Flower story	Plant life cycle Hidden story – Bee trip and pollen Hidden story – pollination and fertilisation
Lesson 4	human lifecycle	Lifecycle story Hidden story – the sex organs and intercourse Hidden story – fertilisation

See appendices C for lesson worksheets.

I followed the groups on video through the sequence of lessons, recording my results and trying to explain my observations and beginning with group A. Sample narratives are recorded in Appendix C.5 and C.6.

Group A's conceptual journey

Lesson A1

In lesson A1 the tasks are to complete the concept board of the human life cycle first presented in the interviews, to sequence a set of diagrams showing the 'hidden' story of fertilisation and convert these into a short narrative. Some more detailed notes of activity and conversation are given in appendix.C.5 and C.6. I did not keep any of the concept boards, as these were identical to those used in the interview and were completed successfully. However some samples of fertilisation sheets and narrative are given in appendix.C.7. The outcome of the lesson was that all pupils appeared to complete these tasks set and presented completed diagrams and convincing narratives.

The group process. The group settled in quickly and listened attentively to the teacher outlining the first task. When the teacher finished speaking and distributed the materials the pupils very rapidly undertook a series of nonverbal gestures, body postures and eye contacts which appeared to be nominations of the person who would actually carry out the task. The target of the group seemed to be Helen, but she turned her gaze away and appeared to refuse the nomination. The group gaze fell on Peter, who reluctantly began to assemble the life cycle. Sandra and Collete chatted absently. In the background the teacher was called to the entrance of the store and asked something by the technician. Dave took the opportunity to shout loudly that he knew the answer – which he then presented as copulation (Driver et al, 1994: 49) the class made no response. Helen chatted on and off with Sandra – a scandal about some other girl conducted in mouthed whispers, but became the target of banter from the boys in group alpha. Dave was

suggesting that she was very knowledgeable about sex and she was protesting about the innuendo, but in a rather flirtatious way. The teacher suddenly called time. Helen pulled Peter's work over and silently approved it. The three girls quickly copied out their own versions.

The class showed greatest levels of concentration when listening to the teacher. All of the pupils were at some stage 'busy' on their own, but for the most part this appeared to be mechanical activity, absently cutting things out or arranging shapes. Pupil-pupil interaction within the group was either chat or copying with a few elements of debate about the sequence of laying down the cards between Colette and Sandra. At the beginning there was the announcement about copulation by Dave to the whole class – there was little response to this beyond a few sniggers. At the end there was a rapid range of glances and remarks from pupil to pupil within the groups and then between groups.

Interpreting the meaning of the activity

I think it worth pointing out again in the context of the classroom observations that the pupils were happy to adopt the tasks set by the teachers and to assume the role of pupil in the classroom setting.

It seemed, however, that being busy was an end in itself, often mechanical and seemingly a way of relaxing or a cover for chat about other things. This seemed to be a greater factor with the girls than the boys. Generally the boys were rather louder but also more enthusiastic.

Reflecting on the different intentions of the teacher and pupils in the situation led me to believe that there were two distinct levels to the activity. One was the formal, explicit purpose of the activity in terms of the concept of reproduction within the human life cycle. The end of this activity was not clearly visible to the pupils. On the other hand there was the informal, implicit social life of the classroom, pupils relaxing, having a chat, exchanging banter which weaves in and out of the actual content of the

lesson. The implicit and explicit were linked together by 'task completion'. The pupils strove to have some product at the end of the lesson linked to the task presented by the teacher. Often this was 'farmed out' through non-verbal exchanges at the beginning of the activity, with the results generalized by copying at the end.

It is also possible to interpret the pupils behaviour through the model of a developmental space. Most of the children either already had, or were close to forming, a concept of reproduction close to the one offered. In that sense the activity was at the very beginning of a developmental zone – confirming what is already known. The suggestion is that there might need to be the sort of tension that Vygotsky suggested was represented by the zone of proximal development for learning to take place. Finally what the pupils succeeded in doing was in essence the assembly of a narrative – a task that Carol Feldman and David Kalmar suggest might be an automatic, inbuilt activity (Feldman and Kalmar, 1996:107).

Activity A 1. 2

Activity A1. 2, a follow-on activity in the same lesson, involved sequencing a series of pictures to outline the 'hidden story' of fertilisation, again to be able to narrate the story.

Outcome

The pupils were successful in the task, in that they produced worksheets that recorded correct sequences in the process of copulation and fertilisation.

Process

Again there was little in the way of pupil-pupil debate. Again the pupils showed great interest and attention. They were very busy with the task sheets, but this appeared to be very mechanical activity. Chat was almost non-existent at the start of the class, but became more strongly developed

later. Almost no elements of the chat involved attempts to elicit the process. Most of the pupils did not know the importance of fertilisation (Driver, 1994: 48) and their solution was to ask the teacher. Brief question-answer sessions between the teacher and small groups or individuals allowed Dave and Colette, for example, to form a correct solution and extensive copying and comparison led to whole-class solutions.

Interpretation

Interpreting the situation from the model of a developmental zone, it appears that the teacher saw the concept of fertilisation as in some way implicit in the situation. This was not in fact the case. The assembly of the different cards into a coherent concept relied on external model provided by society. The cards could only be used as scaffolding in these circumstances – a reality indicated by the brief bursts of teacher-pupil interaction which appeared to aid the pupils concerned in moving quickly to an understanding of the role of fertilisation. The greater difficulty may be linked to the fact that the concept was not in fact a narrative form, but is more readily understood as a scientific model.

Lesson A2 – build a flower

Task – to construct a model flower using a flower kit and set on instructions, with the vocabulary of a real flower – carpel, stamen and so on.

Outcome – all successful – each group produced a completed and accurate model flower.

Process

Again the groups were very quick to settle and to concentrate on the teacher's instructions. The groups automatically split into pairs and worked together in concentration, readily using the vocabulary to denote the part they wanted. There was some indication of an understanding of a

connotative function in that they had to put pollen (sulphur dust) on to the anther and use Pritt to make the stigma sticky. Discussion about this showed a ready use of the structures of language to imply relationships between the parts of the flower and hinted at a connection between structure and function.

This said, the level of reflection was quite shallow. After a short time the construction took on an absent-minded, automatic aspect. Chat and play increased as time went on. Each pair panicked in turn when they could not find the carpel. This was not present because it had to be constructed in a sub-assembly. There was no attempt at deduction or debate. The first group to be stuck immediately asked the teacher and most pupil-pupil communication within the formal task was simply passing on the teacher's explanation.

Boys were somewhat more enthusiastic than the girls, but also more dependent and more inclined to play towards the end of the activity. There was less copying but to some extent the activity looked less challenging.

Interpretation

This lesson tends to support the points made in the last lesson. On reflection, from the perspective of a model of a developmental space, it is not clear that this activity actually involves progress through the space. The pupils could carry out the activity without any model of reproduction and it is only when they connect to the real flower and its functions that progress can be assumed. If this is so, then it is evidence that task completion is the goal of the pupils and they feel no cognitive conflict if the activity does not appear to have any meaning. What seems to have occurred is extremely rapid initial assessment of the difficulty of the task. Once it was assessed as easy the pupils committed themselves to it, but without any goal on their own part to form new concepts or challenge old ones or feeling any need to reflect on the activity. Engagement in the task and being able to carry out the explicit instruction to construct the flower was sufficient. I would

interpret the gender difference as being in part linked to the differing levels of maturation. The girls in general had a higher level of social skills and were able to commit to chat interlinked with activity. The boys were less skilful at chat and this meant a greater involvement in the task at the beginning but also a tendency to more obvious banter and play when the task proved less demanding.

Lesson A3 – Flower dissection

Task – dissect and name flower parts for a number of different flowers

Outcome – pupils carry out activity successfully. All the groups produced cards with the parts of the flower sellotaped in the correct boxes.

Process – initially the pupils work individually, but quickly join into pairs and easily and automatically use the science vocabulary to identify the parts to each other. The transfer of the science vocabulary occurs unselfconsciously. Hand lens use is quite skilful and does not appear to involve any doubt or hesitation, despite relative infrequency of its use in the laboratory. As time goes on the process seems to become more mechanical. Chat increases and non-verbal agreement leads to one pupil doing the actual work while others observe languidly, with the odd direction or comment.

A defining moment comes when Sandy finishes a dissection, mounts it on a card and asks the teacher if it correct. The teacher directs him to his partner, Dave. Dave explodes angrily; “*Don’t ask me – I don’t know*” (with the clear implication that it is the teacher’s job to correct). The teacher becomes quite anxious about pupil inactivity and moves around trying to force individuals to be less passive. The activity does not fit the expectations of his model and he is unthinkingly trying to force reality to fit the model.

Activity A3.2 – Pollen and ovule

Task – the pupils are to identify pollen and ovule after examining them under a microscope and show, by linking structure and function, that they identify them as sex cells or gametes.

Outcome – The pupils appear perfectly happy examining the pollen and ovule and seem to recognise them and link them to the work they have been doing. They do not however seem to understand that they are part of the system of sexual reproduction of the flower. Asked to link the structure of the gametes to the function they carry out they simply draw rough labelled diagrams.

Process – The pupils examine the samples individually. They seem interested and excited and remark to each other about the appearance of the pollen and ovule – “*It’s like an emerald*” calls out Sandy. However conversation does not move beyond appearance and no-one asks other pupils or the teacher about the function of the gametes.

Interpretation. – Again task completion seems the dominant activity. The pupils show little curiosity and do not ask about the gametes. The pupils would now succeed in answering correctly many elements of the Key stage 3 paper questions on flower structure, but do not appear to have moved along the developmental space to form a concept of plant reproduction. This is in line with other research that indicates the difficulty that the task seems to pose (Driver, 1994: 50).

Lesson A4 – Beetrip

Activity 4.1 – the plant life cycle – is completed quickly and accurately without a great deal of thought.

Activity 4.2 – construct narrative of bee pollination and subsequent conversion of ovary to fruit.

Outcome – success, with some mistakes in sequencing. The groups produced sequenced cartoons of Bees collecting and delivering pollen and the subsequent withering of the flower and growth of the fruit. A number of pupils were quite vague about the role of the Bee and confused because there were two bees.

Process – Again the pupils pay close attention. Initial cutting of cards is automatic. Sandra and Colette glance at each other. Both are holding the card and both want to cut. Without any real pause, and without a word, Sandra tears the sheet in two and they both cut happily. Later Colette takes charge of the sequencing while Sandra kibitzes. The activity is low-energy and there is no discussion of the task. Some of the boys are evidently completely off-task and the teacher excludes Charlie for a time because he insists in talking very loudly about football.

Again task completion is the children's goal. They feel no cognitive conflict and do not reflect on the meaning of the tasks given. The teacher evidently believed that there was some internal pressure in the situation that would push the children to understanding of the mechanism of pollination and fertilization, but the children seem happy with an unorganised heap of impressions.

Activity 4.3 – pollination and fertilisation– construct definitions of pollination and fertilisation from diagrams showing the process and key words supplied.

Outcome – a number of pupils provided the expected outcome, but somewhat in the nature of providing the solution to a crossword rather than showing a genuine understanding of the processes involved. There is a great deal of confusion, of off-task behaviour and appeals to the teacher.

Process and interpretation – The teacher has expected that the concept would emerge from a developmental space by being constructed from earlier activities. In fact this does not happen. A certain expectation of meaning has held the activities of the teacher and pupils together, but now there is confusion and frustration. The girls chat and the boys get stuck and play. Some boys demand support from the teacher and the outcome is miniteaching events where the teacher responds with questions and draws out a series of statements which he confirms or denies until the pupil arrives at a satisfactory conclusion. Task completion for the other pupils is a wave of copying running across the class at the end of the session.

Group B's conceptual journey

Lesson B1 – build a flower

Task – to construct a model flower using a flower kit and set on instructions, with the vocabulary of a real flower – carpel, stamen and so on.

Outcome – all completed identical 'mutations' with sepals inside petals. Vocabulary used automatically.

Process – Initially all pupils interested and attentive. However once activity began the levels of play and chat were higher than for group A. In part this was due to one pupil, Bart, with a specific learning difficulty. He stood out in that he made no concessions at all to the explicit task of constructing a model flower. His exceptional behaviour in making the implicit social aspect of the activity explicit threw into sharp relief the willingness of the other pupils to accommodate the stated purpose of the lesson and 'borrow' the teacher's goals as part of their own activity. Even Bart assumed the demeanour of the on-task pupil when under the direct observation of the teacher. As it was he went through an amazingly inventive routine of all the things you could do with the kit parts until excluded for a time by the

teacher. The extent to which this was seen as exceptional behaviour was illustrated by the fact that the other pupils eventually turned away in disgust to at least attempt the class activity.

The class then settled to assembly, but with rather low energy. As with A, they had problems with the carpel. There was a greater level of chat and play. When the teacher demanded completion Margaret swiftly completed the assembly and the rest of the class copied.

Interpretation

As with A group, the activity could be divided into explicit and implicit levels linked by the goal of task completion. I saw the pupils as being confused because they were attempting to model the flower with any full concept of plant reproduction or context of human reproduction. The activity appeared meaningless and levels of engagement were less. I believe the lower levels of energy encouraged the adoption of the mutation. The 'petals' were green and at the beginning of a developmental space perception would dominate. Vague memories of the outside of the flower being green would be enough to produce Margaret's mistake. Low levels of energy meant the absence of reflection and unthinking copying. A correct structuring would have been secured by an understanding of the flower as the reproductive organ of the plant. The mode of thought – folkbiology – that would have allowed understanding was not present (Carey, 1996: 202). I began to suspect that my picture of a developmental space was mistaken. Rather than ascending from perception to the concept the pupils needed the concept to 'ascend to the practical' and structure their perception of the flower (Davydov, quoted in Engeström, 1996: 159-160).

Lesson B2 – flower dissection

Activity B 2.1 - flower dissection

Outcome – overall success and adoption of vocabulary to new situation – some exceptions and confusion.

Process – level of interest rather lower than group A. Pupils are slumped and rather glazed. Brian was an extreme example. He slumped with his head in his arms and then sprang into action. His first dissection was completed in minutes, with bits of flower jammed into boxes in the record sheet. This was task completion without any meaning for the pupil. Brian then began to chat and play. Pupil-pupil interaction in the rest of the class was limited. The vocabulary of flower parts was used but in a denotative way – there was little sign of more structured sentences that would have shown understanding of the flowers role as a reproductive organ.

Background noise, confusion and play

Activity B 2.2 – microscopic examination of pollen and ovule.

Outcome

Pupils glanced at the parts under the microscope but showed little interest and exchanged few comments. They copied some notes unto the back of the worksheet. The teacher showed some anxiety and began pressing individual pupils for explanations, but received only reluctant, muttered replies.

Interpretation

Although vocabulary was transferred from the model flower to the real flower, meaning did not follow. In a developmental space it appears that the concept comes first and dominates perception. The pupils did not have a concept of plant reproduction with which to interpret what they saw and

hence saw nothing they could clearly understand. The actual structure of the situation had rested on 'discovery science' ideas and some of the pupils had demanded more guidance from the teacher and looked to the teacher to provide significance.

Lesson B3 – Beetrip

Card construction of the plant life cycle – is completed quickly and accurately without a great deal of thought.

Task – construct narrative of bee pollination and subsequent conversion of ovary to fruit.

Outcome – more or less correct sequences, but the focus is on the bee and not on pollination

Process – 'Pass the parcel'. Brian rejects the worksheet by pushing it away. Alfie reluctantly begins work. Eventually a general busyness in which everyone joins in, with a mixture of chat and work. However when the teacher calls time final decisions are made without discussion. Martin orders; "*stick it (representation of ripe fruit) in there*" and Alfie obeys without question.

The second session, meant to elicit definitions of pollination and fertilization, produce greater confusion. The pupils collaborate in that they take turns to write short notes, but there is almost no discussion and little indication that they really know what they are doing.

Interpretation. Confirms last lesson. Meaning is largely absent. The pupils complete tasks but they lack meaning. On reflection it appears that they lack both the concept and the mental structures that would support the formation of a mature concept.

Lesson B4 –Human life cycle

Task – to complete human life cycle and go on to sequence diagrams of copulation and fertilisation in order to arrive at definition of fertilisation.

Outcome – life cycles completed but concept of fertilisation and zygote formation appear to be absent.

Process – relaxation at teacher introduction and renewed interest but life cycle assembled quickly – Brian calls out and Brian sticks down without discussion. Then chat and play until teacher protests. Millicent and Cath ask the teacher to check their sequence but he refuses, saying that they are in charge.

Second task leads to widespread giggles and banter but the understanding arrived at seems to be that copulation leads to pregnancy. Sperm and ovum only receive peripheral attention. Teacher presses for detailed answers but refuses requests for dialogue and the pupils largely give up. Slowly writing vague notes when the teacher is present, chatting and playing when he moves away.

Interpretation

Again an absence of meaning, due to many of the processes already listed. An extra dimension is added when groups A and B are compared. There seems to be some evidence that the human life cycle, taken first, provides a residual meaning that provides structure for pupil activities when they attempt to understand plant reproduction but that attempts to study plants without already holding a concept of plant reproduction is both ineffective and can act as a barrier to understanding human reproduction.

Overview of the classroom observations

An overview of the classroom observations suggested to me that the children's behaviour could be viewed as spread along a dimension from ontask to offtask behaviour. The ontask behaviour was formal and directed at the explicit goal set by the teacher. The offtask behaviour was informal and bound up with implicit aspects of the situation, leading to chat and play. Mostly these behaviours were purely social, but they did interact with other aspects of the situation, as when the topic of the human life cycle interacted with banter about how much individuals knew about the facts of life.

The pupils seemed usually to begin by adopting the classroom activity presented to them by the teacher. They accepted the structured situation presented to them without question but often did not adopt the teachers goal fully and showed little indication that they understood what that goal was.

The implicit, unstated aim of the teacher was that the pupils would form a new conceptual model of reproduction, but explicitly he asked them to carry out specific tasks by discussing amongst themselves. The intersection between the aims of the teacher and the aims of the pupils was task completion. The pupils carried out the task or produced the work demanded but did not feel the need to go further and incorporate new meanings into their mental structure. Their implicit aims appeared to be largely social. The beginning of each task appeared to involve a rapid assessment of its difficulty. A sort of silent coercion seemed to deliver difficult tasks to an individual while the rest of the group relaxed. On the other hand there was a lot of competition for easy, mechanical tasks.

The expectation that meaning would arise from pupil interactions was usually not met. The vocabulary of the science concepts was used without question, but simply in its denotative sense and only on rare occasions was any greater structuring seen. The reverse was often the case. Pupils indignantly denied that they had any role in judging the truth or falsity of

the outcome and consistently demanded teacher intervention to provide meaning and structure or to assess what they had already done.

An expectation arising from a Vygotskian approach would be that the formal structure of schooling would allow metacognition – that the pupils would reflect on what they knew, know that they knew it and be able to observe the process by which they gained knowledge ‘from outside’. This was not observed as an activity of the individual pupil nor as an aspect of pupil-pupil activity within this pupil group or with this activity. What was observed on occasion was a rapid exchange of questions between the teacher and the individual pupil. This exchange seemed to be a form of intersubjective metacognition, with the teacher questions acting as a form of scaffolding and forcing the pupil to re-examine and structure what they knew.

An assumption of the model of a developmental space that I began with was that the individual could interact with nature in something of the way that Piaget advanced, constructing meaning with the word mediating to allow a more complex generalised process to take place. The evidence of the classroom observations does not support this. It appeared to me that there were close linkages between the children’s behaviour and their position on the developmental space that I had posited. When group A assembled the human life cycle there was little tension and a fair amount of chat because they were consolidating what they already knew. They were able to advance from this to an understanding of fertilisation and to follow the structuring of the model flower and then the real flower. Beyond that point their comprehension failed and play and chat took over.

I believe that a key point came with the observation of the pupils studying the pollen and ovule under the microscope. The element of perception was there, as were the technical words, but they did not lead to understanding and this understanding was not available in the next task of defining pollination and fertilization. On reflection it appears to me that this would never be the case. Perception, even with the mediating influence of the

word, would not lead to the automatic assembly of the concept. Rather the process occurs in the other direction. The pupils required the concepts of pollination and fertilisation in order to structure their perception of the plant cells under the microscope. My view now is similar to that advanced by Lois Hood-Holtzmann. The dialectical unit of concept formation is simultaneously tool and result (Hood-Holtzman, 1996: 89). The scientific concept of reproduction is both the outcome of the activity and the tool needed to assemble itself fully. The struggle for the pupil, according to Davydov, is to 'ascend to the practical' (Davydov, quoted in Engeström, 1996: 159-160) and restructure their understanding of a range of phenomena in the light of the new concept.

The comparative aspect of the classroom study seemed significant. It clearly made a great difference to group B that they began with the plant life cycle rather than the human life cycle. Group A, beginning with the human life cycle, seemed to be able to assume a background level of meaning that supported them through most of the activities. Group B seemed to struggle throughout. This lends support to the findings by Driver et al (Driver et al, 1994: 50) and by Osborne and Freyberg indicating that plants are not seen in the same light as animals (Osborne and Freyberg, 1985: 6). There was also in group A support for Driver's finding that understanding of human reproduction was based on copulation producing babies, without an understanding of the scientific concept. Bruner's idea of the relative ease of a narrative Aristotelean process as opposed to a more abstract and symbolic Galilean process seems to offer insight here in suggesting that the pupils could more easily approach a human narrative than the abstract scientific model that would illuminate a plant biology standing alone (Bruner, 1996: 95). It seems to me also that the classroom observations bolstered Carey's view of an innate 'folkpsychology' (Carey, 1996: 202) or of Mithin's idea of a mental module supporting social intelligence (Mithin, 1996: 88-95) that allowed for an acceptance of the human life cycle but indicated that the pupils did not hold an innate 'folkbiology' that would have supported

understanding of the plant life cycle. (Again there is some support for this in Mithin, who argues that understanding of the natural world and of living things is often couched in terms of an anthropological understanding).

Conclusion

In chapter seven I attempted to look at concept formation in the classroom. I expected to produce grounded theory on the mechanisms of concept formation and of intersubjectivity. The study appeared to confirm the Vygotskyian perspective on intersubjectivity rather than the Piagetian. Vygotsky saw concept formation as developing intersubjectively when the learner worked with a more knowledgeable other. The pupils groups did not have this structure and an expectation on my part that the structuring of the situation by teaching materials and teacher instruction would compensate and allow concept formation did not bear fruit. There was some evidence that it would have been possible for the teacher to provide a form of intersubjective metacognition through miniteaching interventions.

More generally there was confirmation of existing research on the sort of misconceptions/alternative conceptions held by children in this area and a suggestion that there may be 'modes of thinking' that structure the formation of concepts.

I will return to this issue after I look at the outcome of the final interviews (chapter eight) and examine the structure of the school knowledge – formally the object of concept formation in school (chapter nine).

Chapter 8

‘Structured situations’ part III

Final interviews

Introduction

In this chapter I will outline the rationale behind the design of the final interviews and the extent to which the design is based upon my assumptions about the nature of a developmental space. The children were sorted into 3 groups – groups A and B of the classroom observations and a group C consisting of pupils from other classes who had followed a more traditional, text-based approach. The responses of the 3 groups are compared, completion times are collected for the frog life-cycle task and those carrying it out first contrasted with the group attempting the life cycle task last.

The final interview set-up

One further difficulty caused by the delay in the timing of the study was the late timing of the final interviews – half on the 23rd of June and half on the 27th, with term ending on the 29th. The main result was to reduce the sample size. 41 pupils had taken part in the initial interviews, but only 25 were available for the final interviews.

The conditions for the final interviews were as those for the initial interviews, held in the science store with a fixed route in and out (see

appendix A.3). They were held in line with the schools child protection policy following discussion with the principal and with the technician present in the background during the interviews.

Again the term interview is something of a misnomer. As in the first set of interviews I intended a set of structured situations that would require a response from the pupil. Cues suggesting elements of the concept would be provided and the pupils would have the opportunity to manipulate the cues to construct meaning.

Interview details

The pupils were asked to generalise from the specific case studies of human and plant to arrange the elements of a Frog life cycle, to identify male and female parts of the flower, explain that this is where reproductive cells were formed, define fertilisation and finally to apply the generalised model of reproduction – male and female cells joining to form a new organism – to an unfamiliar problem.

Because, at what I expected to be an end point in a developmental space, I expected to find evidence of a greater variety of concepts and structures, the situation is more heavily weighted towards the interview. In the initial interview there had essentially been one concept and a number of tightly focused cues to be manipulated into a meaningful pattern. In the final interviews I am looking for a broader spread of related concepts and the cues are rather loosely focused. An interpretive element of the interview attempted to establish which of the sub-concepts were understood by the pupil. In a comparative element the questions were alternated between a schedule which asked about animal reproduction first and one which asked about animal reproduction last.

The interview schedule was as follows:

1. Here are cutouts of a frog life cycle (Appendix D.4). Can you set them down to tell the story of the of the frog life cycle? (The time to set out the cycle was recorded.)
2. Can you tell me the story of the frog life cycle?
3. Here is a diagram of a way of growing carrots indoors (see appendix D.2). You chop up the carrot, put the pieces in a special jelly and you get lots of small carrots. Scientists call this asexual reproduction. Why is it called reproduction?
4. Why is it called asexual?
5. Here is a cutaway picture of the inside of a flower (see appendix D.2). Can you point to the male bit?
6. Can you point to the female bit?
7. Now, can you tell me why the male bit is called the male bit?
8. Now, can you tell me why the female bit is called the female bit?
9. This is a picture of a seed (see appendix D.3). A few seconds before it was there as you see it, but it wasn't a seed. What has happened to turn it into a seed? (If response is fertilisation, ask what that means).

The questions assumed a rough hierarchy of knowledge as follows:

Understanding reproduction as an increase in the number of organisms
(Question 3)

Ability to identify the male reproductive organs of the flower. (Question 5)

Ability to identify the female reproductive organs of the flower. (Question 6)

Ability to state that the male reproductive organs of the flower contain male reproductive cells. (Question 7)

Ability to state that the female reproductive organs of the flower contain female reproductive cells. (Question 8)

Ability to deduce that fertilisation occurs just before seed formation (Question 9a)

Ability to define fertilisation as the union of male and female reproductive cells. (Question 9b).

This sequence of questions is transposed with the sequence 3—4—5—6—7—8—9—1—2 in alternating interviews, so that half the sample were asked about an unfamiliar form of animal reproduction at the beginning of the interview and half at the end, essentially repeating the plant – animal transpositions of the earlier parts of the research.

The overall structuring of the situation was in accordance with my model of a developmental space. The questions, taken as a whole, and not in the order in which they were put, were meant to map out a steady progression from a basic, undifferentiated understanding of animal reproduction to an identification of plant reproductive organs, being able to state their function and hence to deduce and apply a generalised scientific concept of sexual reproduction.

Process

Pupils readily accepted the situation, accepted the goals of the teacher and showed great concentration and emotional interest, with a great deal of anxiety about their success with the questions.

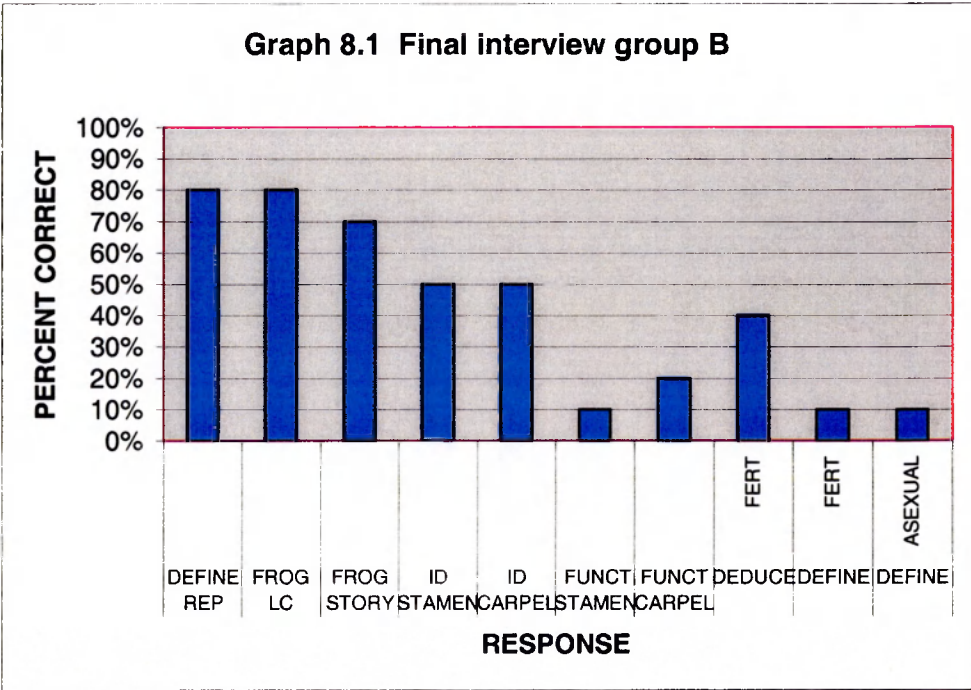
Outcome:

The vast majority of the pupils (20 or 80%) were able to define reproduction as an increase in numbers of organisms. 2 pupils (8%) were unable to define reproduction and 3 (12%) had a confused or unclear understanding. There were some indications that everyday understanding of human sexuality or human growth blocked development of a broader scientific understanding. Only a few (3 or 12%) showed evidence of understanding what asexual reproduction was and 4 others (16%) showed a confused unclear conception – this sort of understanding of the difference between sexual and asexual would have indicated a very deep knowledge of the scientific significance of sexual reproduction. The small number of pupils who had such understanding seemed to base it on information obtained from the home or from independent reading rather than to have developed the understanding from classroom activity and discussion.

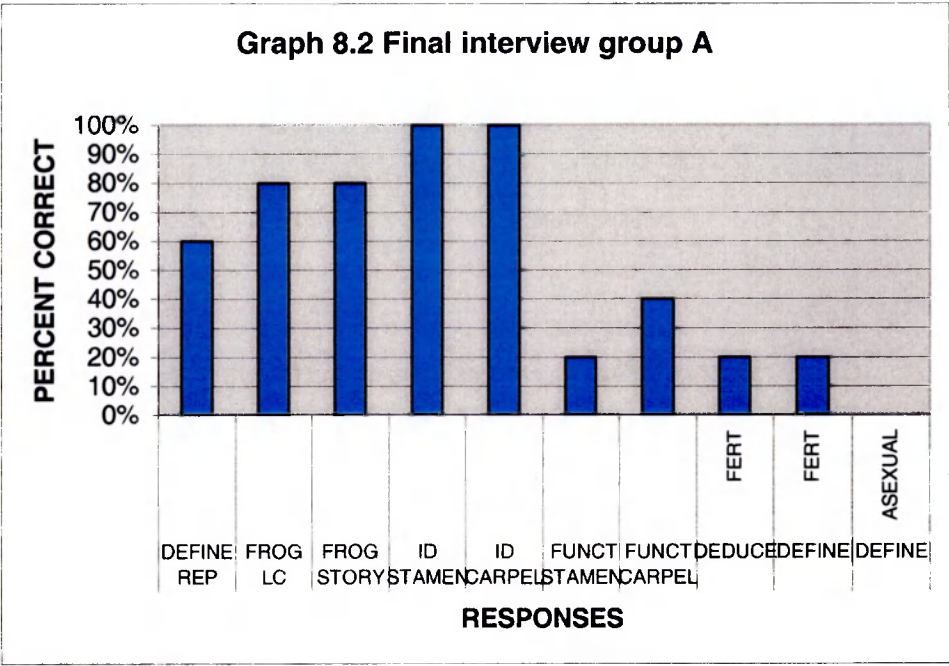
The majority of pupils were able to identify the stamen (19 or 76%) and carpel (18 or 72%). However only 6 pupils (24%) were able to indicate that the stamen was the source of male reproductive cells and another 6 pupils showing elements of a confused understanding. The pupils achieved almost identical results for the carpel (7 showing understanding of the concept, 5 a confused understanding). The majority of the pupils (21 or 84%) were able to construct a frog life cycle and 19 of these were able to narrate the sequence of events within the frog life cycle.

It is possible to walk through my imagined developmental space by graphing the relative success of various groups of pupils. It is however important to bear in mind that a large majority of pupils did not demonstrate that they had formed a scientific concept of reproduction.

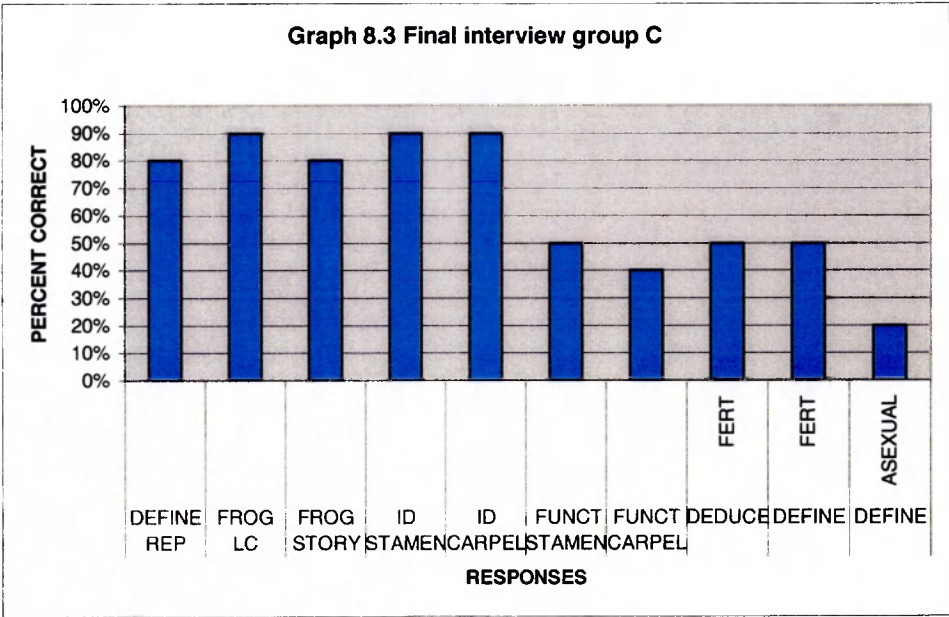
Graphs comparing the performance of the groups are as follows:



Graph 8.1 shows that a majority in group B, who studied plants first in the classroom, appear to have general understanding of reproduction and some understanding of fertilisation, but the majority appear not to have formed the formal concept and hold something closer to the Vygotskian complex.



In graph 8.2 group A, who studied humans first in the classroom, show a similar pattern to B, but with a much stronger response in relation to plant reproduction.



In graph 8.3 group C, who were formally taught following the book, show the highest level of success in suggesting the formation of the formal concept, although even here many did not move beyond basic ideas.

Interpretation

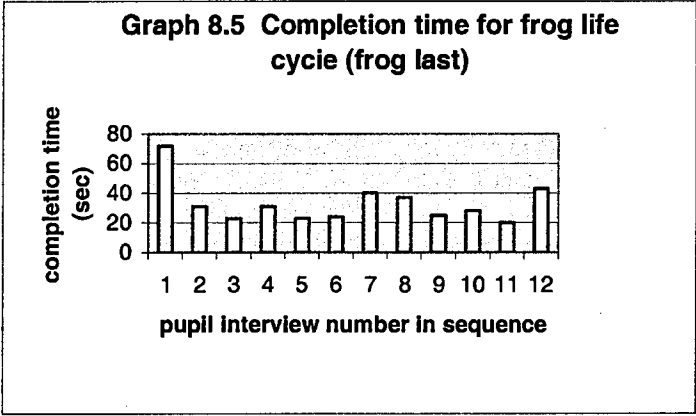
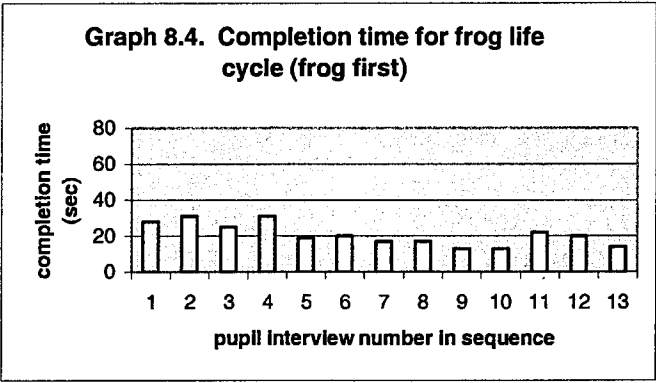
Group C are a group of pupils who were taught by other teachers using the conventional textbook exercises.

The graphs are not a highly reliable source. The small numbers involved mean that a mistake by single pupil indicates a shift of 10, and sometimes 20 percent. However the pattern that arises from comparing results is plausible and is to some extent supported by the earlier finding of the study. The graphs show:

A sizable majority of pupils in all the groups can provide a simple definition of a life cycle. Group A, who examined the human life cycle first, outperformed group B in identifying the male and female parts of the flower. However group C outperformed both A and B when it came to defining the functions that the reproductive organs carry out. Groups A and B did not appear to have developed a clear concept of the role of pollen and ovule. It is worth noting that I did not count as giving a correct answer a sizable number of pupils who were not able to answer clearly. Many of these pupils appeared to hold concepts of growth and copulation which, rather than helping them advance towards a more advanced understanding, actually acted as a block to further development..

Contrasting element of findings

As in the initial interviews and the classroom observations, it was possible to compare the pupils who completed the frog life cycle first with those who tackled it last. The results are as follows:



The average completion time was 21 seconds for those pupils who attempted the task at the start of the interview and 33 seconds for those who attempted it at the end. The order of tasks appeared to have a significant effect on outcome.

Interpretation

Some accidental features of individual variation account for part of the result. Of the pupils who showed least knowledge, two were absent from most of the lessons, two were exceptionally weak with a strategy of completing tasks as a way of avoiding stress rather than reflecting on the plausibility of their answer and one is believed to be suffering from ADHD. Group C contained a large number of pupils assessed as being more able. However the overall pattern seems to fit in well with other aspects of the study.

The most consistent pattern, found in other parts of the study, is that the order in which tasks are attempted – human or animal first or plant first – has a major impact on the time taken to complete a task. This supports findings by Driver et al (Driver et al, 1994: 50) and Osborne and Freyberg (Osborne and Freyberg, 1996: 88) that children consider plants to be different entities and lends support to suggestions that thinking may be constrained by a narrative mode (Oatley, 1996: 128) or a social intelligence (Mithin, 1996: 88-95). Even more plausibly it suggests a ‘folkpsychology’ rather than folkbiology as a way of organising mental processes (Carey, 1996: 202). The fact that group A, which studied the human life cycle first, outperforms group B also supports these possibilities.

The major surprise of this element of the study is the relative success of group C, taught through conventional text-based studies, compared with both A and B. The science book texts begin with an outline of the concept of fertilisation, then plant reproduction, then human. On reflection I see this as pointing to a major fault in the model of a developmental space that I began with. The idea that initial perception, even aided by the word, would assemble into a mature concept now seems unlikely and too close to the Piagetian model. My view now is that it is the model which works backwards along a developmental space to structure perception. This leads to a rather difficult dialectical conception which Hood-Holtzman calls ‘*both tool and result*’ (Hood-Holtzman, 1996: 89). The formal concept is both the outcome of the developmental space and the major element in its formation.

Finally it is worth noting the number of confused answers with links to copulation and to concepts of growth. This suggests that earlier concepts may not act as a base in the development of later ideas but may in fact become a barrier to conceptual progress – what Engeström calls encapsulation ((Engeström, 1996: 155).

Conclusion

In this section of the study I have explained the connection between my model of a developmental space and the way in which the final interviews were structured. The outcome was to suggest that formal concepts were not formed by the majority of pupils. Again the group who studied human reproduction first outperformed the group that did not and again there was a difference in timing between those who took the frog life cycle first and those who attempted the question last. The results suggest again that different modes of thinking may come to play in different situations, with the narrative form the most accessible. The major surprise of the final interviews was the better performance of those not involved in the classroom study, leading me to further question my initial model and to consider restructuring the model to take account of Hood-Holtzman's idea of the formal concept as a combined tool and result.

Chapter 9

Deconstructing Texts

The contextual element

One of the elements that should be considered when addressing the issue of concept formation and movement in a developmental space is that of context. For the post-modernist, there is nothing beyond action in a social setting, seen as the irreducible element of being (Slife and Williams 1995: 52). For the mutualists, action in a social setting is both constituted by human action and is also the medium in which that action occurs (Still, 1998: 93). For Lave and Wenger learning is both a function of the learner and of the social environment (Lave and Wenger, 1996, 145).

In the light of the above it would appear important not to take the context of schooling as a given. I plan to examine one particular element of context in school, that is, the formal goals of the learning process as presented in curriculum materials. In line with the rest of the study, the exemplar material will be the science curriculum elements dealing with reproduction as presented in:

NICCEA Key Stage three curriculum

The textbook in use in the school

NICCEA Key Stage three assessment material

In order to present a full picture I will also examine the curriculum as it was presented to the classroom observation groups A and B.

I believe it useful to consider the texts from the following perspective, to some extent the linking themes for much of the work in this study.

Is the curricular material part of a developmental space in which the concept acts as an organiser, linking and structuring other concepts? This idea is presented by Ian Kinchin, who argues that individuals can build a concept map that begins with one superordinate concept and progresses in a hierarchical way until the 'bottom' of the map is reached with concrete examples of the concept (Kinchin, 1998: 2). In this case the key idea would be the science model of male and female gametes fusing in fertilisation to form a zygote or new organism.

Are the concepts in the curricular material structured by superordinate structures, not simple concepts but rather worldviews on which they depend for full meaning as suggested by Vygotsky? (Vygotsky, 1971:68).

Does a narrative structure or a hypothetico-deductive structure, as proposed by Bruner (Bruner, 1996: 95 –98) underlie and structure the texts?

To what extent can explicit structures be identified in the texts and to what extent would these be accompanied by underlying implicit structures?

Syllabus

The science syllabus content for reproduction at key stage 3, as presented by the curricular authorities (NICCEA, 1996: 13), is as follows:

PLANTS

Learn about the structure and functions of the component parts of the flower (limited to a named dicotyledonous plant), including names of the parts – sepals, petals,

nectaries, stamens, (anthers and filaments), carpels (stigma, style and ovary) and receptacle,

- *self and cross-pollination, insects and wind as agents of pollination,*
- *fruit and seed dispersal - wind, animals, water and explosive mechanisms,*
- *seed structure - radicle, plumule, cotyledon, testa, endosperm,*
- *seed germination (limited to a hypogeal seed),*
- *investigate the conditions which affect germination – temperature, adequate water, oxygen supply.*

ANIMALS

Be introduced to the structure and functions of the component parts of the reproductive systems in humans, including:

naming the parts of the male system - testes, scrotum, sperm ducts, prostate gland, urethra and penis, naming the parts of the female system - ovaries, oviducts, uterus, cervix, vagina and vulva.

- *fertilisation in the oviduct,*
- *role of the placenta,*
- *birth (limited to contraction of the uterus and dilation of the cervix)*
- *find out about the requirements to maintain healthy bodies and healthy babies during pregnancy.*

(above taken from NICCEA (now CCEA) Key stage 3 syllabus, 1993: 13 and 14)

Deconstructing the syllabus

Organising concept?

Quite clearly the model of fertilisation is not an organising concept for the syllabus. It is mentioned only once, in the section about human reproduction, and is not mentioned in the plant section at all.

Superordinate structures

There appear to be two superordinate structures. One, not mentioned in this extract, is the section of the syllabus within which the element of reproduction is situated. It is listed with nutrition, respiration and so on, under the heading 'life processes'. This would appear to be itself based on the materialist, as opposed to the vitalist tradition of modern science. The idea of organisms as operating a mechanical way with material processes as explanations for the functions of life is a relatively modern one. However life processes would be a relatively weak organiser and its significance is not made explicit in the syllabus. What is of major significance is the related concept of structure and function, repeated throughout the syllabus. This is the idea that body structures adapt and shape themselves to function – again this concept is not made explicit and is presented only via examples. Finally there is a concept of health and social concerns.

Text structure

The syllabus contains both hypothectico-deductive and narrative structures. The listing of names and the linkage to structure and function suggest larger structures in some way explained by the assembly of substructures. There is also a narrative structure listing plant and human life cycles, but this follows behind the hypothectico-deductive and appears somewhat subordinate to the initial structuring.

Implicit and explicit

The explicit element of the syllabus is an account of structures and processes of plant and human reproduction. Implicitly there is a heavy reliance on technical vocabulary that appears to present science as authority. This authority appears to be used in the syllabus to reinforce knowledge about health. It also seems likely that the practice of presenting plant reproduction first, given its relative unfamiliarity, is a way of making safe and scientific a rather difficult topic for teachers and for society in general.

The text

The flavour of the Science Now! text (Fullick et al 1996: 106-121) can best be given by summarising 'Key ideas' given at the end of each chapter. The sequence is as follows:

- Fertilisation is the joining of a male and female sex cell.
- Pollen made in the stamen of one plant lands on the stigma of another. This is called pollination. The pollen fertilises the ovules in the ovary and these develop into seeds and new plants.
- Fruits help seeds disperse using wind or animals.
- Testes are male sex organs which make sperm.
- During puberty a girls ovaries start producing an ovum (egg) each month.
- During sexual intercourse sperm are released. If a sperm meets an egg fertilisation takes place.

- The menstrual cycle lasts about 28 days. If an egg is fertilised it will implant on the wall of the uterus.
- When a woman is pregnant she has a growing fetus in her uterus. The process of giving birth is called labour.

Organising concept?

The science model of fertilisation is an organising concept in the text. It introduces the section and is restated in each section when explaining plant and human reproduction. The centrality of the model is not always evident because of the heavy narrative structure of the text (see appendix F.1)..

Superordinate structures

In line with the syllabus the main concept repeated throughout the section is that of structure and function. Again, this is not made explicit – examples are presented in each section.

Text structure

The vast majority of the text is organised in a narrative format. Even the key concept of fertilisation is presented as a journey. Insofar as hypothetico-deductive elements are present, mostly in diagrams, they are balanced by a greater number of pictures and illustrations.

Implicit and explicit

In some sense what appears to have become implicit is the science dimension of the topic. The question of human reproduction is presented in some detail as a narrative and health issues are covered. In the background is quite a lot of science – the issue of structure and function, line diagrams of processes, the fertilisation model and a large technical vocabulary. The narrative structure however, appears so overwhelming as to make invisible

alternative ways of structuring the information. The model of fertilisation is not used to investigate processes, rather it structures narrative. The technical vocabulary is dealt with in a narrative format, printed in bold with definitions and then followed up and consolidated with cloze procedures. Again plant reproduction comes first and this appears again as a way of making safe a rather difficult subject.

The assessment material

Some exemplar material is presented in appendix F.2. In general the questions are structured around line diagrams. Pupils are required to identify elements of the diagram using the correct scientific vocabulary. It is only in the later stages of the questions that the pupils are asked to demonstrate knowledge of fertilisation. There appears to be a hierarchy of answers, linked in the marking scheme to levels of attainment. Initial achievement is around naming parts. The next level is based around structure and function and the highest level appears linked to an understanding of the process of fertilisation.

Organising concept?

Both structure and function and fertilisation are key concepts in the questions.

Superordinate structures

It appeared to me that the concept of science as fact and authority rather than science as investigation was dominant. For example, where names were requested the mark scheme was based on recall of the technical vocabulary and no marks were available for meaning or understanding.

Structure

The structure was very definitely hypothectico-deductive. Questions were based on line diagrams and on substructures from which the whole was formed. Explanations were in terms of structure and function and function in turn depended for its definition on the process of fertilisation.

Implicit and explicit

As assessment material the questions in general were, of course, implicit, with the candidate given the task of providing meaning.

Groups A and B

Group A's schedule is shown below:

Lesson 1	human lifecycle	Lifecycle story Hidden story – the sex organs and intercourse Hidden story – fertilisation
Lesson 2	Build a flower	Use of empty concepts
Lesson 3	Flower dissections	Linkage of empty concepts Microscopic view of pollen and ovule
Lesson 4	Flower story	Plant life cycle Hidden story – Bee trip and pollen Hidden story – pollination and fertilisation

Group B's schedule was as group A, with lesson 1 taken last.

(This information is also presented on page 94)

Organising concept?

In both group's work the model of reproduction was present but rather than being an organiser it was the implicit goal of activity, to be constructed by the pupils out of the activity. For group A the elements of the model lay within the reasonably familiar territory of the human life cycle. For group B it lay within unfamiliar territory of the plant life cycle.

Superordinate structures

The organising structures here are the reproduction model itself and the constructivist model of concept formation, both visible only to the teacher.

Structure

From the teacher's perspective the structure is hypothetico-deductive, meant to reveal the model of reproduction from a scientific perspective. From the pupils point of view it may appear as a series of unconnected narratives.

Implicit and explicit

The implicit structures are the science perspective on reproduction and the teacher's constructivist stance. What is explicit to the pupil is a series of tasks, mainly based on sequencing or narrative.

Overall Interpretation of texts

It could be argued that the formal concept of reproduction is an indirect organiser of the syllabus in that the syllabus is organised fairly tightly around the concept of structure and function and in this case the function is reproduction. This seems to me to be stretching the point. When we follow the structure and function concept as organiser it tend to explain pollination

and copulation respectively as the process around which structure is built, rather than explaining fertilisation, an invisible outcome of the process. In fact understanding comes from the other direction, with fertilisation giving meaning to the other processes and to the structures. In my view the lack of the formal concept of reproduction as a direct organising principle, along with the concentration on structure and vocabulary, suggests a particular view of science as composed of unquestioned factual elements. A common criticism of the syllabus is that it is too heavily weighted towards content and I feel that this reflects an approach to science as a series of facts. The concentration on structure and vocabulary tend to an overall impression of authority rather than discovery or inquiry, an impression which is strengthened by my analysis of both book and exam questions.

The textbook appears to provide the concept of fertilisation as an overall organiser, but it does so within a narrative structure. This seems a valuable approach, but there appears to me to be a gap between the narrative approach of the text and the hypothectico-deductive of the assessment material and of science as a whole. It seems to me that for the concept to be fully expressed it has to transfer from narrative to hypothectico-deductive structure.

Further insight can be gained if we use a perspective taken from the classroom observations – that there are different levels of meaning, which are sometimes contradictory, within the social setting. At one level, the level of explicit meaning, the syllabus is a list of science concepts which must be learnt. At another level, the implicit level, there are a whole series of social concerns which are reflected in the syllabus. The most important of these concerns is the difficulty and danger of the taboos of giving sexual information to children. From this perspective it makes a great deal of sense that both the syllabus and the textbook begin with plant reproduction. This establishes from the beginning that the activity is scientific, abstract and safe. It also tends, I think, to reinforce the idea of science as fact and authority.

A byproduct of this implicit structure of the curriculum is that it tends to fragment the explicit curriculum. Without the formal science concept of fertilisation as organiser there is a tendency for the pupil's understanding to break up into what Vygotsky called pseudoconcepts (Vygotsky, 1971: 66) and what Engeström calls "encapsulated knowledge" (Engeström, 1996: 155). This suggests two kinds of formalism in school. One is the scientific formalism which Vygotsky referred to and which he saw as progressive and liberating for the pupil. The other is the situated cognition identified by Lave and Wenger, where pupils learn to be schooled and find it both unnecessary and difficult to integrate school knowledge with their everyday, spontaneous concepts (Lave and Wenger 1999: 21-27).

Another aspect of school knowledge, pointed out by McDermott, is that it contains within the school situation the expectation that pupils will fail and that there will be a hierarchy of knowledge. Both success and failure are built into the school structure, he argues, awaiting individual pupils to take their place and be labelled (McDermott, 1999: 18). If this is the case then the full scientific understanding of fertilisation, at the top of a hierarchy that I suggested was built into the syllabus, would not be available to the majority of pupils.

Conclusion

My final interviews found that many pupils – those involved in the classroom observations and also those taught conventionally, did not form a formal scientific understanding of reproduction. Analysis of the syllabus and other texts suggests that there are likely to be different levels of activity in school – the explicit task occurring alongside other goals that are implicit in the social situation. I suggest that this may prevent the development of a full concept and that alternative pseudoconcepts may form instead and that the conflict between implicit and explicit may be linked to Vygotsky's praise of the formalism of schooling and Lave and Wenger's suggestion that the situation merely allows us to learn to be schooled.

Chapter 10

Revisiting the literature, reviewing the model

Introduction

I began my research with the assumption of a model of developmental space in which concept formation could take place. The model saw the concept beginning with 'lower' mental processes that were largely automatic, the again automatic adoption of the word as an 'empty concept', initial meaning as coming from the denotative function of the word and from expectations arising from the structure of language and then a whole series of linkages and association leading, in the right conditions, to the formation of a formal concept through a series of 'heaps' and 'complexes' that were loose associations of ideas rather than concepts. In school science I assumed the abstract procedures of science would operate, with the outcome being the formal scientific concept. I now want to look at the extent to which the research supports that model and, to the extent that it does not, look again at the evidence to see if it is possible to modify or replace it with a new model.

To what extent did the research support the initial model?

The initial interviews

I did not observe 'lower' mental processes, nor should I have expected to. These occur too rapidly for the techniques I was using to detect them – the best I could do was to observe that pupils had different problem-solving strategies when manipulating the cards. I consider standard positivist experimental techniques to be of more utility in observing initial aspects of perception and action – the 'crisis of psychology' does not arise here because consciousness is not a factor in the timeframes of 0.2 – 0.3 seconds over which the phenomena occur. As John Shotter comments, the human can become object and the subject of psychology behaviour (Shotter, 1975: 15). Nonetheless these processes are still important because they filter consciousness at this early stage and because the adaptive processes involved, as in Dennett's idea of 'multiple drafts' competing within the mind to define the situation, may illustrate how some 'higher' processes operate (Dennett, 1991: 112).

With the expectation that adaptation within 'lower' mental processes might effect higher processes I looked at Edelman's theory of TNGS (the theory of neurone group selection) (Edelman, 1992: 83-87). The processes that he describes would occur too quickly to be detected by the techniques that I was using. However I felt that there remained an important element to the study which also applied to my work – that is the suggestion that the initial stages of lower mental process involve a process of adaptation not governed by the rules of formal logic or under conscious control. I would tend to argue by analogy that we would expect to find adaptive processes in the initial elements of higher mental functions. The work of Rita Carter on form and perception contains similar references to adaptive processes, but goes on to argue that filtered input from the senses moving upward interacts with existing conceptions moving downwards (Carter, 1998: 19). This sort of dialectical process was, I feel, missing from my existing model of a

developmental space. For example, just how basic some biological categories may be is illustrated by Rita Carter when she recounts the story of a patient who, because of damage to her perceptual systems, could not recognise any kind of living thing other than other humans, but had normal perception of non-living objects (ibid: 116). Later in the same section she explains the operation of a 'Face recognition unit' that automatically identifies people that we know (ibid: 122).

One weakness of the initial interviews was my failure to fully consider the conceptions that the pupils were bringing to the situation. Osborne and Freyberg argue, with some justification, that these should be the lynchpin around which the curriculum should be organised (Osborne and Freyberg, 1985: 84). An important point of their 'generative learning' theory would be the assertion that pupil's learning is constrained by what they already believe rather than by Piagetian stages. Instead of looking at the question of generative learning, my starting point was the last element of the primary curriculum that they had studied – the single-cycle life cycle. More or less accidentally I found, when attempting to construct a more realistic cycle involving sexual reproduction, the persistence of previous ideas – attested to by Vygotsky, by Carey and by Osborne and Freyberg. My feeling following the interviews was that the phenomenon was best understood, not as some generalised persistence, but as a process I would now call 'encapsulation' – the idea put forward in Engeström that special mental structures form during the process of schooling. Of some interest was his linking of the process of encapsulation with a model of school learning where the outcome was to successfully answer the teacher's questions rather than any deeper understanding of the phenomena (Engeström, 1996: 157). I believe that the failure of a number of pupils to resolve the new life cycle is best understood as encapsulation.

An aspect of the initial interviews that caused surprise was the emotional aspect that I had not considered. In a 'tutorial' situation the pupils not only

adopted the goals of the teacher but showed a great deal of anxiety to meet the goals.

There is, I think, strong evidence for an aspect of a developmental space not fully considered by me initially – that of different modes of thought. One of the strongest elements of the research was the continuing discrepancy in all the structured situations between sequences which began with plant reproduction and those that began with human reproduction. I believe this is strong evidence that we find it easier to think about some aspects of reality rather than others. There is a great deal of debate about the nature and number of innate intelligences and the extent to which they are innate or acquired, but researchers such as Mithin and Carey agree that at least a ‘folkpsychology’ and ‘folk physics’ (social and technical intelligence according to Mithin) are fundamental elements of human thought and both agree that ‘folkbiology’ or ‘natural history intelligence’ arise from social intelligence through process of analogy mapping across domains (Carey, 1996: 206) – in Mithin’s case the analogy is anthropomorphism (Mithin, 1996: 48). I would also tend to argue for the plausibility of a view that we tend to think in certain ways rather than others – that the structures of narrative come easier to hand than the more abstract models of science. Bruner, while making this point, argues that we can link the two in the history of science, when analogy and metaphor are initially used to construct models from narrative (Bruner, 1997: 124)

It should also be noted that thinking about thinking, or metacognition, was not a usual aspect of most of the structured activities, although a few pupils showed signs of very deep individual reflection, including whispered conversations with themselves, in the initial interviews. I now believe that processes of formal logic and metacognition would be endpoints of the developmental space rather than starting points

Finally one of the most useful aspects of the research was my development of the ‘structured situation’ – the idea that meaning could be potentially present in a situation and be assembled by the pupil. Initially I drew upon

the ideas of Margaret Donaldson (Donaldson, 1987: 69) and Osborne and Freyberg's 'interviews about instances' (Osborne and Freyberg, 1985: 6-8). However, when I came to contrast the relative utility of the materials and prompts in the initial and final interviews I began to see that this was not the whole story. I believe now that the encapsulated idea of a single asexual life cycle stood at one pole of a 'zone of proximal development', with spontaneous knowledge of human sexuality and copulation forming the other pole. It is only when in a ZPD that the structured situations can be usefully used to explore a developmental space. In some ways this can be seen as a reverse perspective of scaffolding. Instead of an external structure lending support it becomes a mechanism for revealing the extent and internal structuring of knowledge. Vygotsky was, as usual, ahead of me in seeing this relationship (Vygotsky, 1971:108). Mariane Hedegaard, while not addressing structured situations, defined the relationship between spontaneous and scientific concepts as the basis of instruction (Hedegaard, 1996: 175).

The classroom observations

One surprise of the classroom observations was the unreflective automaticity of what Vygotsky would have considered 'higher' level mental functions. I observed this in very rapid processes which establish the 'aboutness' (defined later in the chapter) of a situation – in the interviews a very rapid adoption of the tasks set and in the classroom group adoption of the tasks is followed by very rapid negotiation between the members of the group about who will carry out which roles. The automatic processes are already social and this something that was absent from the initial model of a developmental space. The importance and strength of these behaviours was shown up by the exception – the ADHD pupil who simply did not share the orientation towards a group activity that the other pupils displayed. Even here the rapid changes of behaviour when under the direct gaze of the teacher showed that the pupil was aware of the behaviour and activity expected, even if he was unable to adopt them spontaneously.

If initial perception and activity were more social than I expected then the use of new technical vocabulary, while fitting into the model I had assumed, was much more automatic than I had expected, in the sense that the word itself, its denotative aspect and initial structuring were all accepted with extreme ease – so great an ease that there was very little sign of the reflection that would presumably be needed in concept formation. The ‘mutation’ of the model flower when group B assembled it so that everyone ended with identical but mistaken models was, I feel, a significant indicator of this lack of reflection.

During most of the classroom activity the teacher was trying to protect his role as researcher by refusing to engage. This led to a struggle with the children, who demanded that he remain in charge of the learning. Eventually he was cornered into a miniteaching episode which seemed, on later reflection, to be a sort of external metacognition – a rapid exchange of questions and answers that led the pupil towards the required answer and also demonstrated the processes that the pupil would have to internalise if she was to achieve metacognition herself. It seemed likely also that metacognition was not generally occurring because we were not at that point in the developmental space. An important tool was the concept of fertilisation itself, which they had yet to form. This appears to echo Hood-Holtzmanns’ idea of the concept as simultaneously tool and result.

The most enlightening observation was the examination of pollen and ovule. In my view the children could not assemble a concept of fertilisation through simply reflecting on the activities and looking at the pollen and ovule and I began to accept the view that in fact the reverse process was the important one – the concept of fertilisation was what allowed an informed perception of the pollen and ovule.

The idea of ‘aboutness’ can be studied further by contrasting pupil behaviour in the interviews with pupil behaviour in the classroom. In both cases the teacher defines the situation and, in both cases, the pupils largely accept the teacher definition without any problems. However the pupils

exhibit a great deal more emotional commitment and concern and are much more clearly on task in the interviews. I would tend to argue that this can best be understood by separating the elements of the situation into implicit and explicit elements. Implicitly the teacher wants concept formation but explicitly what is asked for is task completion. In the interview the gap between implicit and explicit is small because the group consists of only two people and the teacher is transmitting both verbally and non-verbally the importance of the implicit element.

In the classroom the implicit elements of the situation are social – the group arranges a division of labour where some pupils carry out the work and relaxed advisors engage in chat and play. Only if the task is assessed as very interesting or easy does it engage everyone and there are small-scale fights over resources. Normally there is very rapid communication leading to one individual undertaking the task while the rest advise and copy. This contrasts very sharply with real science, where the group would tend to have a shared goal as well as shared tasks. In the classroom the outcome is task completion and this appears to me to aid the formation of pseudoconcepts. At the end of the process we get a form of encapsulation of some aspects of the situation which can be reproduced successfully in exams. Flower structure seems to me an example of such synthetic knowledge.

In my model of developmental space I had expected intersubjectivity to be structured by the props and vocabulary of the structured situations and lead the pupils upward through a developmental space to the concept. This did not happen. The main reasons for failure were that the differing goals of teacher and pupils were met through task completion and also because I now see the chief organiser of the structured situation as being the concept itself. A more realistic model of a developmental space would work backwards and use the concept to explain phenomena rather than phenomena to explain the concept. This view of the concept as organiser is echoed by Grady Venville in her study of concept formation in secondary school genetics. (Venville, 1977: 245).

The final interviews

One of the main elements of the final interview, noted earlier in the chapter was to suggest that structured situations were a special form of scaffolding of use as a research element only to the extent that they were situated within a zone of proximal development. The props and prompts of the final interviews did not seem to be so situated. The failure of the majority of the pupils, no matter how the topic was approached – group A, B or traditionally taught from the textbook – to form a fully developed formal scientific concept of reproduction could not be fully investigated with the research instrument that I used. I suspect that a much tighter focus, for example creating the possibility of linking copulation and fertilisation, would have been more effective.

From this viewpoint I began to look again at what constituted scaffolding. The evidence from the final interviews seems to indicate that the long period of work in constructing model flowers was not effective. Group C, exposed only to labelled diagrams, were just as effective at identifying the parts of the flower as group A and far more effective than group B. The model flower kit seems to me to be an example of mental tool that pointed outwards. A more effective tool, pointing inwards, were the concept boards themselves, generating very detailed concentration and reflection in the initial and final interviews and, in one case, what was clearly a process of deduction. I tend to believe now that the concept itself acts as scaffolding. The evidence in the study is that on the one hand, the failure of the ovule and pollen investigations to ‘build upwards’ to help generate concepts and on the other, the relative success of group C who began their unit on reproduction with a brief narrative account of the process of fertilisation which appears to help organise their later work.

The syllabus

The key stage 3 syllabus for the North of Ireland, very similar to the British syllabus, also has implicit and explicit aspects. Explicitly it is about science

– but where science tends to mean authoritative, factual and certain rather than about any process of enquiry or investigation. Implicitly it appears to me that the consistent practice of dealing with plant science first is a way of dealing with taboo – of establishing that the coming conversations between the adults and children about human reproduction are safe and scientific. In addition the syllabus contains a tension between narrative structuring and hypothetico-deductive, scientific ordering. These tensions, of implicit and explicit, science and narrative are repeated to some extent in the other curricular texts. The result, I believe, is a tendency to allow a fragmented understanding made up of separate, encapsulated elements, a tendency reinforced by Key stage 3 exam question that focus on vocabulary and on labelled diagrams. Again this was a process recorded by Venville as occurring in the Australian syllabus (ibid: 243)

It seems evident that one outcome of the research process should be a revised picture of what I mean by a developmental space, but in order to do so I will need first to revisit the literature.

Is there an automatic aboutness to social situations?

I would tend, on reflection, to situate the automatic elements of a social situation much higher up the table of mental functions. Rather than being concerned simply with elements of perception and action they embrace a whole panoply of social behaviours necessary for us to operate in a group. I have termed this ‘aboutness’. Aboutness is defined by Daniel Dennett as intentionality – the ability to select and attend to salient aspects of a situation. He sees this skill as being made up of an ensemble of more basic skills of perception and action (Dennett, 1991: 333). My definition differs somewhat in that in this case I see it as an intersubjective skill, made up of very rapid, mostly unselfconscious, negotiation between the members of a group about the nature of a situation and the division of tasks.

What my research was able to suggest as an automatic starting point of a developmental space was the immediate establishment of the aboutness of a

situation in the classroom immediately followed by rapid nonverbal negotiation of roles. This automatic comprehension of a social situation is attested to by Donaldson. She argues that young children interpret communication by a combination of understanding the language itself, interpreting the intention of the teacher, mainly through non-verbal cues and lastly by an interpretation of the situation (Donaldson, 1987: 69). She argues that when we consider the task of decentering we should distinguish between the child's appreciation of what the other sees and their appreciation of what the other is feeling or planning to do. The latter, she argues, is a very fundamental human skill (ibid: 15).

Bredo argues that mental processes occur within a holistic world of thought and action (Bredo, 1999: 28). It would follow from this that the situation itself and the sort of mental activity and role required must be the product of extremely rapid processes. We do not normally observe people deciding on the requirements of a situation and then undertaking mental activity. When on occasion people adopt an inappropriate response to a situation it is detected immediately by those around and often causes embarrassment. . In humans plan and action appear one reflexive process, with many actions occurring automatically as movement takes place. (ibid: 30). Bruner argues that in entering social situations we make use of minimal cues. We '*do not linger*' in our decisions about the nature of a situation (Bruner, 1974: 142).

Wood refers to semantics and pragmatics – 'hidden' rules of communication – how the meaning of utterances is influenced by the relationship between speaker and listener and the social situation (Wood, 1989: 162). It is suggested that a special type of mental structure called a script allows us to make sense of routine activities (Taber, 2002: 27). Joiner et al suggest that the simple presence of peers, even without communication, can significantly change outcomes (Joiner et al, 1998: 301).

Can social situations be seen as composed of implicit and explicit levels?

To some extent the quote from Wood in the paragraph above, and the references in Donaldson suggest this implicit and explicit relationship. Donaldson is, I feel, arguing that the child attends to meaning and that the meaning is in the social situation rather than fixed firmly by formal logic or the literal meaning of questions (Donaldson, 1987: 69).

Bruner strongly supports this perspective with evidence from research in Africa. Facts are facts because the teacher says so – there is no need for independent checking (Bruner, 1974: 48). Discussions are finished when an unanswerable point is made – and social status often makes points unanswerable (ibid: 49). He sees social situations as divided into intrinsic and extrinsic elements (ibid: 78).

Lave and Wenger argue that legitimate participation unites thought and action in a culture to make one unified reality from which meaning emerges – and that it very rarely emerges from any simple logical sequence (Lave and Wenger, 1996: 145).

To what extent does language share this automaticity of social situations?

The position of Stephen Pinker, drawing on Chomsky, would seem to be that language, while produced automatically and spontaneously through an innate mechanism, is highly rule-bound and structured and thus constrains situations through its internal logic ((Pinker, 1998: 118). Still draws on Wittgenstein to argue that language itself has implicit and explicit levels – in this case the pole of meaning on the one hand and, on the other its use to carry out actions and meet goals (Still, 1998: 92).

In fact there are strong arguments that there is a great deal of automaticity ‘higher up’ a developmental space. Mithin argues very convincingly that humanity, from the beginning, had a form of social intelligence that enabled

us to read the goals and feelings of the other, and that transfers into anthropomorphism, making it easier to form models of the behaviour of prey for example. This would suggest that much thinking is unreflective, drawing on unconscious assumed metaphor. Carol Feldman and David Kalmar argue that the mode of thought in which cognition naturally arises is narrative. Genre is a specific mode of thought arising from narrative and also imposed on it by the reader (Feldman and Kalmar, 1996: 1060). Again, there would be a series of assumptions about the 'story' that would inhibit reflection. Carey argues that an innate 'folkpsychology' acts as the structure on which more modern modes of thought, such as 'folkbiology', are based. The suggestion of innateness is not meant by Carey to suggest genetic determinism, but it is meant to suggest an inbuilt, automatic mechanism that is deployed reflexively in new situations (Carey, 1996: 190).

I find myself rethinking the role of speech. Throughout this study I have seen speech as one of the higher mental processes, by its very nature containing meaning. The unthinking adoption of vocabulary by the pupils, with very little reflection, forced me to look again.

Peter Smagorinsky argues that speech and other mediational tools are simultaneously higher mental functions and the intersubjective tools out of which the higher mental functions can be built (Smagorinsky, 1994). Pinker's insistence on genetic determinism in language acquisition suggests a certain unthinking dimension to its use (Pinker, 1998: 118). Wittgenstein separates meaning from language use in determining action and goal (Wittgenstein quoted in Still, 1998: 91).

What converts unthinking speech into a new conceptual understanding? My suspicion would be that metacognition, when we turn back and review our understanding in the light of a new concept, building new linkages and mental maps, is when speech and meaning unite.

Encapsulation

An inbuilt automaticity could be taken as a strong reason why movement along a developmental space often does not lead to full concept formation. Without reflection mental structures dominated by perception, by language and by the internal assumptions built into modes of thought can form and persist. Vygotsky listed heaps, complexes and pseudo-concepts as mental structures that were likely to form, with only the pseudo-concepts persisting (Vygotsky, 1971: 59-67). Permanent structures, not formal concepts, that persist sound similar to some characterisations of misconception/alternative conception. Engeström presents a new light on misconceptions or encapsulated knowledge when he presents the work of Wagenschein who argues, from a study on misconceptions about phases of the moon that schooling often produces 'synthetic stupidity' (Wagenschein quoted in Engeström, 1996: 155). What is of special interest about the misconception – that phases of the moon are caused by the Earth's shadow – is that it is easily disproved by direct observation. The argument is that 'empty sentences' formed in schooling actively block knowledge.

Engeström produces a model of such learning where the object of school activity are not about the phenomena under study but about displaying the text presented (ibid: 157). This seems close to my own observation of task completion as a shared goal of classroom activity. The requirements of the tasks in the classroom observations were met by a formal representation of the information. The pupils seemed well aware of this and lacked interest in any need to produce meaning.

A similar finding was produced by Grady Venville in her study of concept formation in genetics. She found that on a four-step construction of what she described as an ontological pathway the vast majority of pupils (44 of 58) did not advance beyond level two (Venville, 1997: 201). If her pathway is

seen as a developmental space then there is no reason to believe that the pupils will advance further from a particle understanding of genes and a form of encapsulation will have occurred.

Models for learning meaning

Engenström presents a number of models to overcome a tendency to 'encapsulation' of knowledge in formal schooling:

- Davydov's view of 'ascent to the practical', where the curriculum is searched for key idea or models and these are then applied to explain phenomena. Davydov argues that this approach in 'instructional psychology' follows on automatically from what he sees as Vygotsky's refutation of the formal local idea that concept formation proceeds through generalisation from the concrete to the abstract. (Davydov, 1985: 59-61).
- Lave and Wenger's view that 'communities of practice' be built within the school and authentic knowledge gained through legitimate participation.
- Engestrom's own view that schools be dedicated to critical study in broader networks of learning (Summaries of the models of Davydov, Lave and Wenger and Engenström in Engenström, 1996: 161-167).

I will return later to the issue of school learning in general. My view of concept formation is now rather similar to Davydov's. We ascend to the practical in the sense that the concept itself is what forms and structures a formal understanding. Hood-Holtzman quotes Vygotsky in seeing method and language as simultaneously tool and result and I believe we can picture the concept as simultaneously tool and result (Hood-Holtzman, 1996: 89). Indeed Vygostky very explicitly makes the point that mastery of a new concept leads to a re-structuring of the ideas from which the concept arose –

our understanding of number changes when we master algebra (Vygostky 1971: 115). He argues elsewhere that sciences can only be understood 'backwards' in that historical processes can only be understood in terms of their outcome (Vygostky, 1926: 14). Support for the idea of tool and result can be drawn from the mutualist view that social structures are both the object of social interaction and also the medium in which the interactions take place (Still, 1998: 93). The concept is at the endpoint of the developmental space and also the major factor structuring that space.

Left to itself the above statement sounds rather like a dogma. It does not make a great deal of sense to speak of a circular, self-referential explanation of concept formation or to appeal generally to an unspecified dialectical process. The concept must begin somewhere. I would speculate that the initial phase of concept formation lies in innate mental constructs such as Mithin's concept of an innate social intelligence ((Mithin, 1996: 69) and in Carey's idea of an innate folkpsychology (Carey, 1996: 210). These enable a human understanding of the protoconcept or model, lent structure by an automatic understanding of narrative and genre (Feldman and Kalmar, 1996: 1060). Bruner argues that the prepositional – in this case the model – is dominated of necessity by the rule of the symbolic and that deduction, induction and abduction tame and decontextualise earlier modes (Bruner, 1996: 99) The concept can then act as tool, re-examining ideas in a new light and building a 'concept map' which re-organises earlier ideas (Taber, 2002: 33).

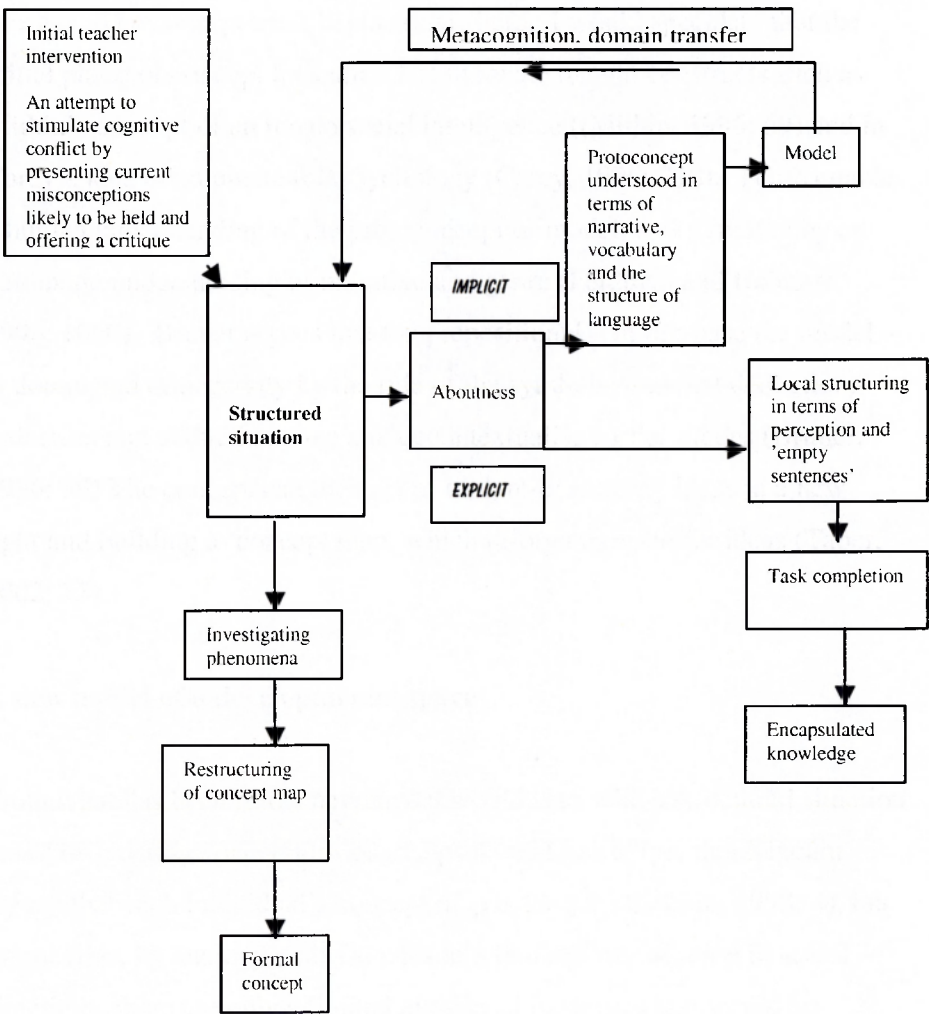
A new model of a developmental space

From what has been said a new model would start with a structured situation based on existing conceptions or encapsulated knowledge. Ian Kinchin argues that each individual's concept map is unique (Kinchin, 1998: 4), but in my view, by analogy with Donaldson's findings on meaning in social situations, there are only a limited number of meanings that would be represented by such maps, even though individual maps would differ in less central respects.

Pupils would establish the aboutness of the situation. If they focus on implicit meaning then they would be in a position to form an initial narrative concept and, by applying the concept to exemplar materials, develop metacognition and transfer from a narrative mode of thought to formal scientific representation. If the pupils adopt an explicit method of task completion without understanding the concept then encapsulation is the outcome.

The model is as follows:

Figure 10.1 – A new model of a developmental space



The significance of emotion

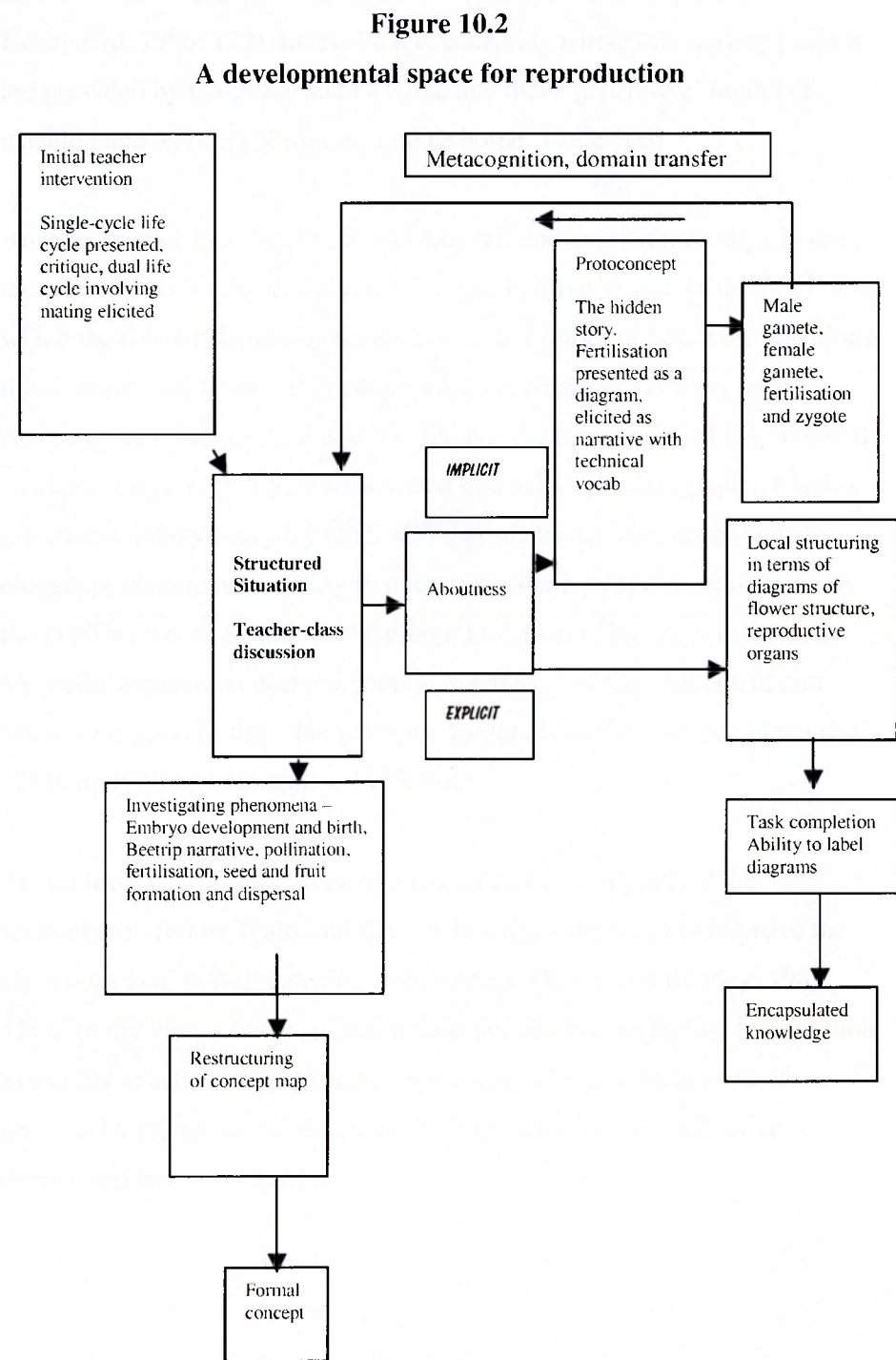
It should be noted that the process depends on the initial structuring of the situation by the teacher taking place in an 'area of tension' – that is, in the zone of proximal development. Mariane Hedegaard follows Leontiev in arguing that it is in the interaction between everyday concepts already acquired and scientific concepts in the process of being acquired that the ZPD lies and where instruction can take place (Leontiev reported in Hedegaard, 1996: 172). Ideas about establishing where this starting point is are provided by Cosgrove and Osborne and their 'generative' model of teaching and learning (Cosgrove and Osborne, 1985: 106)

Another crucial area is in the area of implicit and explicit meanings in the structured situation. It seems to me that this involves issues of the extent to which the teacher dominates the situation. In tutorial or interview situations the teachers' implicit meaning dominates. In classroom activity and especially in group work, this is less likely. We hear stories of inspirational teachers able to impart their own vision of a subject to their pupils, but this seems an unlikely everyday method. What seems decisive is emotional charge, producing real anxiety in interview situations and contrasting with the pupil's relaxed attitude in the group. Lois Hood-Holtzman notes that Vygotsky expressed concern about the separation of the intellectual and affective aspects of life – but promptly forgot about the affective in the rest of his study (Hood-Holtzman, 1996: 80).

At one level paying attention to the role of emotion might lead the researcher to follow Watts and Bentley in suggesting ways to improve the classroom as a 'non-threatening environment' (Watts and Bentley, 1989: 159). In my view what is at issue here is not emotion as feeling but emotion as pointer to action. Rita Carter tells the story of a patient, robbed of emotion by injury, who found it totally impossible to make effective decisions (Carter, 1998: 81).

From this perspective what links intellect and emotion is goal. It is when the pupil share the goal of the teacher that she becomes emotionally involved. One of the special features of school life is that the goal of activity is often not clear to the pupil and not shared by them. When the implicit goal becomes explicit learning occurs. When the implicit and explicit diverge mere schooling and encapsulation result.

The new model, applied to reproduction, would look like this:



Conclusion

In chapter 10 I looked again at my model of a developmental space. It did not hold up to the tests imposed by the research. In many ways it retained elements of Piagetian 'discovery learning' Implicit in the model was a solitary learner, ascending with little effort from activity to concept formation. In the real classroom intersubjectivity, culture and emotion define goals and, even in a dialectical process of concept formation, the concept tends to structure phenomena, not the other way around.

Drawing on the insights of the investigation and the literature I am proposing a new model. Like Davydov, I am ascending to the practical, from the general theoretical construct to the practical application (Summaries of Davydov, in Engenström, 1996: 161-167). The model is not regarded as final, but hopefully presents a closer approximation to reality. The task of redefining goals and guiding emotional engagement are difficult ones. Lois Hood-Holtzman claims that a definitive theory of learning will have to engage with history (Hood-Holtzman, 1996: 93). Given that in the history of many pupils there is the knowledge that school, like schooling, produces failure alongside success (McDermott, 1999: 18) we can see how difficult the generalisation of science concepts will remain.

Chapter 11

Overview

Before I make any attempt at further development of the ideas in the main body of the thesis I intend to contact the objects of my research. I include in this my teaching colleagues and staff at the school, the pupils involved and their parents. Given that the responses and actions of the pupils and other actors are their own, to that extent the work is jointly produced with the pupils and others. If I apply the perspective of the research to the research itself it can appear, from my individual perspective, to make itself explicit as an individual work with one author. However the implicit framework is that I am embedded in a social situation where I depend on the responses and actions of the pupils, the co-operation of the parents and other members of the school community and a range of assumptions from the Open University and the academic community generally about what constitutes authentic and legitimate educational research.

Within that framework I have a number of responsibilities to the people who took part in the research. The most important of these is a duty of care. The main duty of care is to ensure that no-one is harmed through being identified in the study. Clearly the school is relatively easy to identify, but I believe that I

have encoded the information sufficiently and left a sufficient level of generality about pupil details to avoid the identification of individuals. I now want the subjects to reassure themselves of that and I want a mechanism where such consultation can take place but that is not so open as to demand amendment of the work from pupils and parents when they feel no strong need to propose such amendments. The mechanism that I intend to use is a letter to all those involved, giving a brief outline of the structure of the work and its findings and the extent to which observation of subjects plays a part in the work. I will inform the subjects that a full copy of the thesis is available from the school librarian and that I am willing to discuss particular sections if anyone feels they have been identified or their responses incorrectly interpreted (BERA, 1992:2).

The research question

In some ways what I have attempted to do in this thesis is a classical journey in conceptual change as presented by Rosalind Driver (Driver et al, 1989:88) and to a certain extent reflects my final model of concept formation. I began with one model, used it as a tool to construct an investigation and research the literature and ended with a new model of concept formation. With this new model I can look back, with a changed gaze, on my earlier conceptions.

My research question asked

To what extent is it possible to define a developmental space based on Vygotsky's theory that charts the learner's movement, during classroom instruction, from initial perception and introduction of technical vocabulary as empty concepts to the internal development of fully formed concepts?

The question was contextual in the sense that the focus of investigation was not learning in general but classroom learning about the topic of reproduction in particular. Implied in the question was the expectation that it would both lead to an advance on Vygotsky's theoretical standpoint and allow new insights from which both teaching and learning could be understood and that it would also allow the development of specific strategies and teaching aids that would assist in the teaching and learning of reproduction.

It is my contention that I was successful in both areas. I was able to develop a general model as shown in figure 10.1 that, I believe, has a great deal of explanatory power and, although complex, is not so complex as to become self-referential and would, in fact, generate a range of questions that are testable and could be the focus of further research.

I was also able to apply the model to the topic of reproduction (see figure 10.2) and generate a model of concept formation in this area that I have subsequently used as the basis of a teaching plan. This involved beginning with the human narrative – beginning with the misconception of the asexual life cycle taught in primary school, constructing through teacher – whole class discussion a narrative of human reproduction, looking at the 'hidden story' and constructing through teacher-pupil interaction an initial model of fertilisation and using the model to 'ascend to the practical' and explain plant pollination and fertilisation.

'Internal tools' used in the sequence that could be further developed as teaching aids were the asexual and sexual life cycle, the fertilisation model itself and the 'beetrip' cartoons used as a sequencing device to construct a narrative of plant reproduction. I was able to test this sequence with a new year eight group but was not able, in the time available, to study the results in any structured way.

and include them in the thesis. However my view is that concept formation using the fertilisation model appeared to occur in the majority of pupils and, in fact, appeared to be largely problem free.

A model of developmental space

A number of insights were generated from the final, general model of a developmental space. The main insight is that the concept, in a sense, forms itself. It follows from this that activities based on 'discovery learning' and group work, at least during the early stages of concept formation, are largely misplaced, that learning occurs in the area of tension around the zone of proximal development and that this usually involves the pupil and a more knowledgeable other – normally the teacher. The division between implicit and explicit demands of the situation in the classroom are normally resolved by task completion and this encourages 'encapsulated knowledge'. Metacognition appears not to be a normal part of internal pupil activity. What I observed were interactions between the teacher and individual pupils, where teacher questions act as a sort of scaffolding. My intuition is that this is the precursor of metacognition occurring, as Vygotsky indicates with other mental structures, first outside the pupil in a social space. I believe that what is being learnt is not only how to conceive of the information presented in a structured way, but also the sorts of processes that will later allow the pupil to interrogate herself. This would suggest that metacognition is more important later in the developmental space and probably used more widely by more able pupils. I was unable to test this thesis because of the skew in my sample due to the fact that locally the 11+ selection system still operated. What seems to be important overall is that the process of concept formation begins with the existing conceptions of the pupil, that it engages initially with a 'way of thinking' familiar to the pupil – normally a narrative structure – and a familiar 'mode of thinking' – normally Carey's folkpsychology or Mithin's 'social intelligence'. My research did not

contradict findings on pupils misconceptions/alternative conceptions as presented in Driver et al (Driver et al, 1994: 48). What it does do is follow Carey in arguing that some misconceptions may be spontaneous concepts formed through constraints on our ways of thinking and support the ideas of Engstrom that other misconceptions are actually the products of schooling – encapsulated mental structures falling outside the bounds of spontaneous concepts on the one hand and the structures of the formal concept on the other.

A key question that I have to deal with is the extent to which my new model is trustworthy and well founded. From a dialectical materialist perspective this can be regarded as two combined questions. At one pole the question is the extent to which the procedures of the research were objective, the sample random, and the conclusions appear to be tightly bound to the data and observations. At the other pole I should indicate the extent to which the meaning I construct 'makes sense', stands as a plausible account of what I observed and is tightly bound into other conceptual frameworks. In my view the study is plausible both from the point of objective tests and from the point of view of providing coherent meaning.

The number of pupils involved in the project was reasonably large. The skew caused by selection would leave open the possibility that the responses may not be fully representative of more able pupils, but there seems little reason to doubt that what was observed would not be typical of many pupils and classes in secondary schools and many comprehensives. The behavioural aspect of the interviews was caught in the timing and in the frequency of different types of response and I was able to compare and contrast the responses of different groups of pupils

24 (2 groups of 12) pupils were involved in the classroom observations, with 16 (2 groups of 8) normally in the foreground of the video programme. The 24 were members of my own science class, so this meant a further skew on the ability range – the class had been drawn at random from the pool left following selection of a ‘top’ class – for some reason this is referred to as ‘mixed ability’. There was a clear reactivity to the unusual circumstances of the study – I had been forced to carry out the observations with groups rather than with whole classes. During the sessions there was initial reactivity to video equipment and to a much greater extent with audio equipment. I think that the pupils were more familiar with the now commonplace video camera than they were with the tape recorder. By using video I restricted very sharply what I could see.

On the other hand, all the indications were that most sources of reactivity died away during the early part of the lessons and the pupils appeared to act in a rather unselfconscious way. By using the video I gave myself the opportunity to focus in on particular groups and individuals and on the microstructure of the situation. I was able to view the situation over and over again and indulge in the reflection from which grounded theory could emerge.

The major behavioural aspect of the study was the influence of the order in which tasks were attempted. It seems quite clear that the children faced substantially more difficulty in dealing with concepts of reproduction when introduced to them first through plant studies. The issue is the extent to which meaning can be assigned to this behaviour and to their behaviour in the study generally.

One question frequently put is the extent to which another observer, observing the same behaviours and situations, would come to the same conclusions about meaning. The answer seems to be that someone with a different ontology would see different meaning, but, as I have gone to some trouble to make clear

the assumptions on which I base my observations, the work can be approached in two different ways. The first position is to assess the usefulness of this perspective as one among others without deciding on its veracity. The problem with this approach, as outlined by Slife, is that this assumes a metatheory which overcomes the apparent contradictions between different approaches (Slife and Williams, 1995: 48). The other approach is to examine the areas of conflict between this ontology and others and look at the conflict from the point of view of deciding which set of perspectives/observations most closely corresponds with reality. If one accepts a foundationist theory then the power to generalise and subsume simpler materialist and idealist positions may carry conviction.

I believe that, in addition to the outcomes of the research, some of the instruments were of use and would deserve further investigation and refinement. Chief amongst these was the concept board. I found the initial interviews illuminating at a whole number of levels because of the light the concept boards and cards cast on pupil thinking. The final interviews were much less effective and I believe that I was lucky in the initial interviews in having a tight focus on a very narrow area of concept formation and in setting the activity at the start of the zone of proximal development. Designing new sets of cards and boards to approach other areas of concept formation would be difficult, but they would prove useful both as diagnostic and research tools. The idea of a structured situation also proved very helpful in making sense of situations and allowing the space to develop grounded theory. On reflection I would argue that that what structured the situation was the concept and that, again, structured situations, where children are forced to assemble meaning from cues and object provided, would prove useful in diagnosis and research. It is worth noting that some constructions, such as the model flower, appeared to point outwards and not to be useful in concept formation.

The value of research

In my view the educational research cycle is complete when it leads to change in the classroom or to change in the body of theory which itself leads to change in the classroom. Stenhouse appears to argue that the cycle can be encompassed within the individual teacher with his conception of the 'extended professional' where he argues both that part of the duty of the teacher is to carry on research to improve their practice and also that true teaching and learning are, in a sense, forms of open enquiry (Stenhouse, 1975: 157). However it appears clear from the context that he is in fact envisaging a community of teacher-researchers, with the education system transformed to acknowledge and reward the successful practitioner. Kemmis extends a further definition of the teacher-researcher in the conception of 'action research'. Here a central conception is the democratisation of a system apparently governed by elites (Kemmis, 1993: 179). The solution is to unite theory and practice as praxis, by recognising that theory is always a guide to action and it is the unity of theory and practice in concrete situations and tasks that theory is tested (ibid: 182). We are able to trust the outcome because the dialectic of movement between theory and practice is always emancipatory and allows us to break with habit and dogma and see things as they really are (ibid: 183). Again, the assumption is of a community of teacher-researchers working together, with the task of researchers being to pull together and generalise the work of the teacher-researchers. Martyn Hammersley replies, defending the relevance of research and pointing out that claims that research is undemocratic rest on the assumption of particular kinds of participatory democracy (Hammersley, 1993: 215) and that claims that the teacher is a skilled professional are contradictory to claims that she is also a researcher (ibid: 223).

In my opinion neither argument is convincing. Kemmis seems to assume a variety of Marxism called structuralism where class relationships replicate themselves in each institution of society. This appears very unlikely. In reality there appears to be a division of labour which would justify research as a separate area. However Hammersley seems to underestimate the democratic deficit in education and the crisis of educational research –he himself quotes Gipps in indicating that the assumptions of educational reforms in the 1980's run counter to the findings of research (Gipps quoted in Hammersley, 1993: 220).

In a review of a landmark report – that of the ‘three wise men’ in 1992 – Hammersley and Scarth provide what I would consider to be the grounds for a more realistic model (Hammersley and Scarth, 1993: 216). They argue that the standard view would be that research informs the formation of policy but that, in the case of the ‘three wise men’ not only is there research which runs counter to the conclusions of the report (ibid: 217) but that the report does not contain credible research evidence on which to base the conclusions – and the authors admit this in the main body of the report (ibid: 219). My view would be that the explicit aspect of educational research is as the authors outline – as informing policy. However there is also an implicit aspect – that a major role of education is to replicate the class relationships of society. In this case research becomes not a body of information to be interpreted, but a weapon to be deployed in whatever way it can be used to meet the implicit needs of the situation. However the two poles are to some extent independent. Educational theory has an internal logic which remains available – even if unused – until a new shift comes in the balance of political forces and the direction of educational policy – this is perhaps the final lesson of a Vygotskian perspective that we can draw from Vygotsky, whose own work was unknown to many researchers for so long.

Following the research

So what then of my own research? I need to draw up a scheme of work to formalise the teaching approach to reproduction that I have arrived at in the course of the study. This will serve as my practice in the future. It should be possible to extend the methods used to the practice of my immediate colleagues and also to other areas of the curriculum – with relative ease to other issues in biology and with more thought to other aspects of the science curriculum. There are a number of broader research questions that could usefully be followed up and I will refer to these in a moment.

Is this the outcome? Some changes in my practice and possibly a small number of colleagues and acceptance (hopefully) of the thesis? This, after all, is the fate of most theses by teacher researchers (Bassey, 1999: 5). There are a number of alternative outcomes:

A diffusion model – the immediate outcomes of the research is taken up as good practice locally and gradually diffuse throughout the profession.

Weak transmission – I rewrite and publish the findings relating to teaching reproduction in the hope that this element of pedagogy is taken up generally.

Strong transmission – I rewrite and publish the findings relating to my general model in the hope that this is taken up generally by the research community and becomes available when there are future shifts in the political climate and the demands that society makes on education.

I hope I will find the energy for the final element of strong transmission. There are a number of reasons why I might expect interest from other researchers. A new perspective generates new areas for investigation and some of those are already apparent.

I have already referred to 'applied' research where the general model of a developmental space is brought to bear on specific areas of the science

curriculum. It would be necessary also to do further work to refine the model. It has a number of areas, such as automaticity and aboutness, that remain rather ill-defined. I also have in mind a number of broader issues that would be worthy of exploration.

Following Carey is it possible to define and differentiate a number of domains of thought? What are the characteristics of particular domains? To what extent do they constrain thinking? Rogoff suggests that different ways of thinking apply in different areas (Rogoff, 1999: 7). Could it be, for example, that an everyday physics would be more 'Piagetian' because elements of it would be prelinguistic while folkpsychology would be more 'Vygotskyian'.

It seems that here might be some value in an attempt to develop a taxonomy of concepts. A rough taxonomy of concepts in the classroom would look something like the following scheme. Pupils come to school with misconceptions/alternative conceptions (Driver et al). These can be long lasting and extremely resistant to change (Carey 1989: 107). Misconceptions may overlap with spontaneous concepts formed through experience or drawing upon metaphor – for example the idea that the womb is some sort of garden in which a seed from the father grows (Driver et al, 1994: 48). In pilot interviews I came across teleological explanations of phenomena where an overarching concept is used to force meaning on events. In addition to superordinate concepts the

concept can be structured by language itself, either by narrative structure or by logical structuring made possible by language. Vygotsky describes heaps and complexes. I have defined these earlier in the study and they appear to be seen as temporary structures. However Vygotsky also listed pseudoconcepts, with the structure of concepts but arrived at through concrete linkages rather than linked by formal logic. There appears to be some overlap between this idea and the idea of 'encapsulated knowledge' arrived at by Engestrom (Engestrom, 1996: 155). Vygotsky also identified formal concepts based on science as an outcome of school knowledge but contrasts this with the mature concept, formed through the fusion of the formal and the spontaneous concept (Vygotsky 1971: 59-67).

The work of Lave and Wenger seems to me to be of some importance. It appears to me, from my reading so far, that the concepts that develop in communities of practice are spontaneous ones. They specifically refer to concepts that are obtained implicitly, absorbed as a process of cultural assimilation, and frequently only available in particular situations (Lave and Wenger 1999: 21-27). In contrast Vygotsky laid great stress on the formal, scientific aspect of school. One possibility would be that when the concept is available as a tool then metacognition and the formation of the formal concept can occur. When the concept is not available as an aspect of metacognition then the processes may well resemble those suggested by Lave and Wenger (ibid) and the students acculturate into 'schooling' – a form of synthetic stupidity.

On a more general note we can speculate about how it might be possible to surpass schooling. My model suggests that students and teacher unite around a goal of task completion. One approach could be to develop a task of authentic science, allowing a genuine emotional commitment that would unite implicit and explicit. Another possibility would be to make it explicit that the task of

the student is to transform herself. In any case there would have to be major changes to the curriculum. The science concept would have to structure the science curriculum in ways that it does not appear to do so at the moment.

Finally we approach the boundary that separates sociology and psychology from philosophy. Piaget's genetic epistemology rested on logic being inherent in nature and/or in the brain. Vygotsky argues very strongly that logic is a cultural construct, existing first in society outside the pupil and then constructed as an internal understanding. Post-modernism suggests that the person acting in a social setting is incommensurable. If all cultural constructs are equally valid then there is no foundationist bedrock on which science can rest. However if the concept works backwards to construct itself then there is an arrow to history. Not only does science allow greater control of nature and generalisation about its laws, it can point backwards to explain the material basis of earlier societies. Lacking the scientific concepts, not only can past societies not explain their future, they are unable to explain themselves. A dialectal materialist approach does not say that historical progress is inevitable. What it does say is that is possible, and that it is made possible by the contradiction between the ideal and the real. We can never hope to untangle one from the other, but we have to assume their existence if we are to make sense of the world.

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J McAnulty

K0180550

**Concept development
in relation to the biology
of reproduction
in secondary science:**

A Vygotskyian perspective

Appendices

Appendix A.1 (Administration and ethics) Parental permission

Our Ref : JMc~VS~H

January 2000

Dear Parent

As part of my professional development in the school I am presently studying for the degree of Doctor of Education with the Open University.

As part of this line of study I will be investigating teaching and learning by Year 8 pupils in the area of plant reproduction.

I would like your permission to include c<f;orenarnw, in this study.

The study will involve recording individual interviews, observation and recording of classroom activity, analysis of pupil work and access to pupils academic records. All names will be encoded to protect pupil privacy.

The information will eventually be published in the Open University thesis library, but you would be consulted before publication if information relating directly to your child is included.

Yours sincerely

J McAnulty

Please return to Mr McAnulty as soon as possible.

Forename Surname

I give permission for *Forename~ to be included in the research project being carried out by Mr McAnulty.

Signed:

(Parent/guardian)

Appendix A.1.1 (Administration and ethics)

Doctorate in Education

Case study on plant reproduction

Administrative permission

Dear Principal/colleagues,

I enclose a report of my Doctoral research to date.

I am about to embark on stage 2. This will involve a number of interviews and classroom observation of year 8 pupils, for which I will be seeking parental and administrative permission.

I will also be seeking support in a number of areas:

Technician time to help with interviews and observation

Some sub cover when available

The help of other members of the science dept, in observing in my classroom.

Permission and substitute cover to observe some science lessons other than my own.

I hope the school community will find the study interesting and will be able to help.

Yours,

John McAnulty

Appendix A.2 (Administration and ethics)

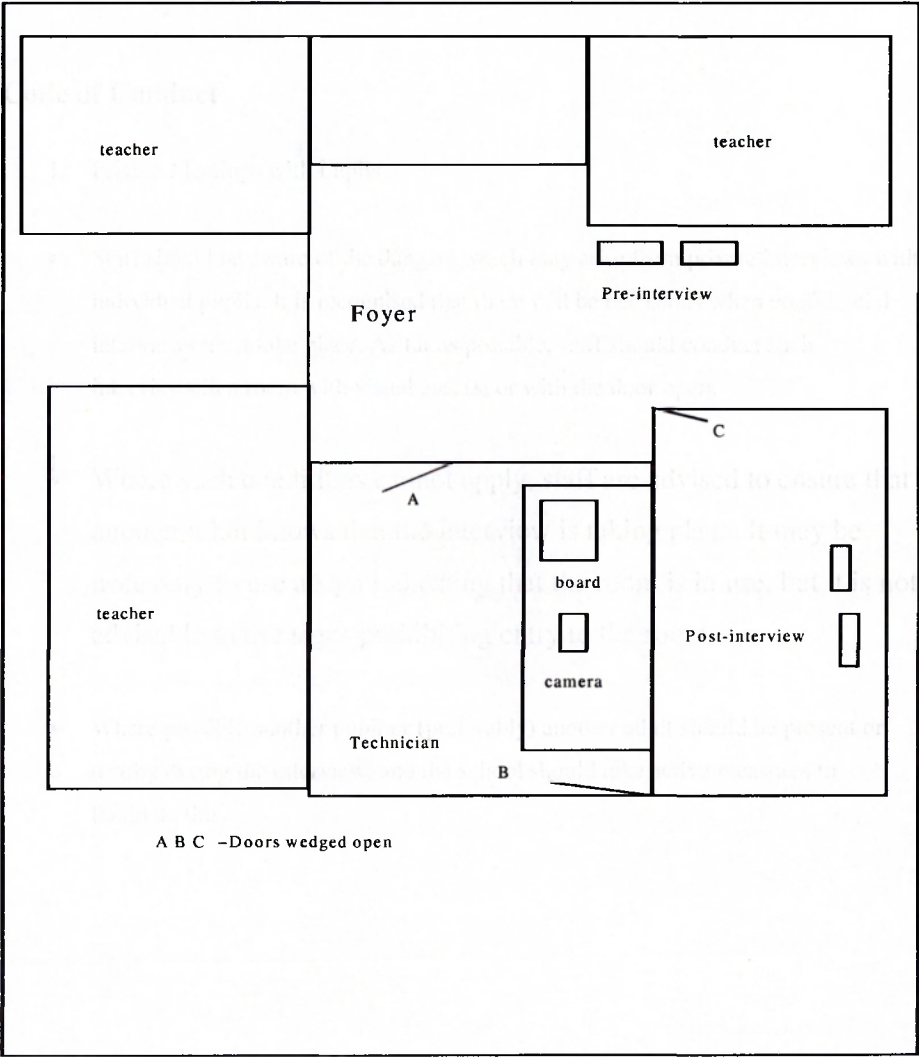
St Fergus's code of conduct regarding interviews

Code of Conduct

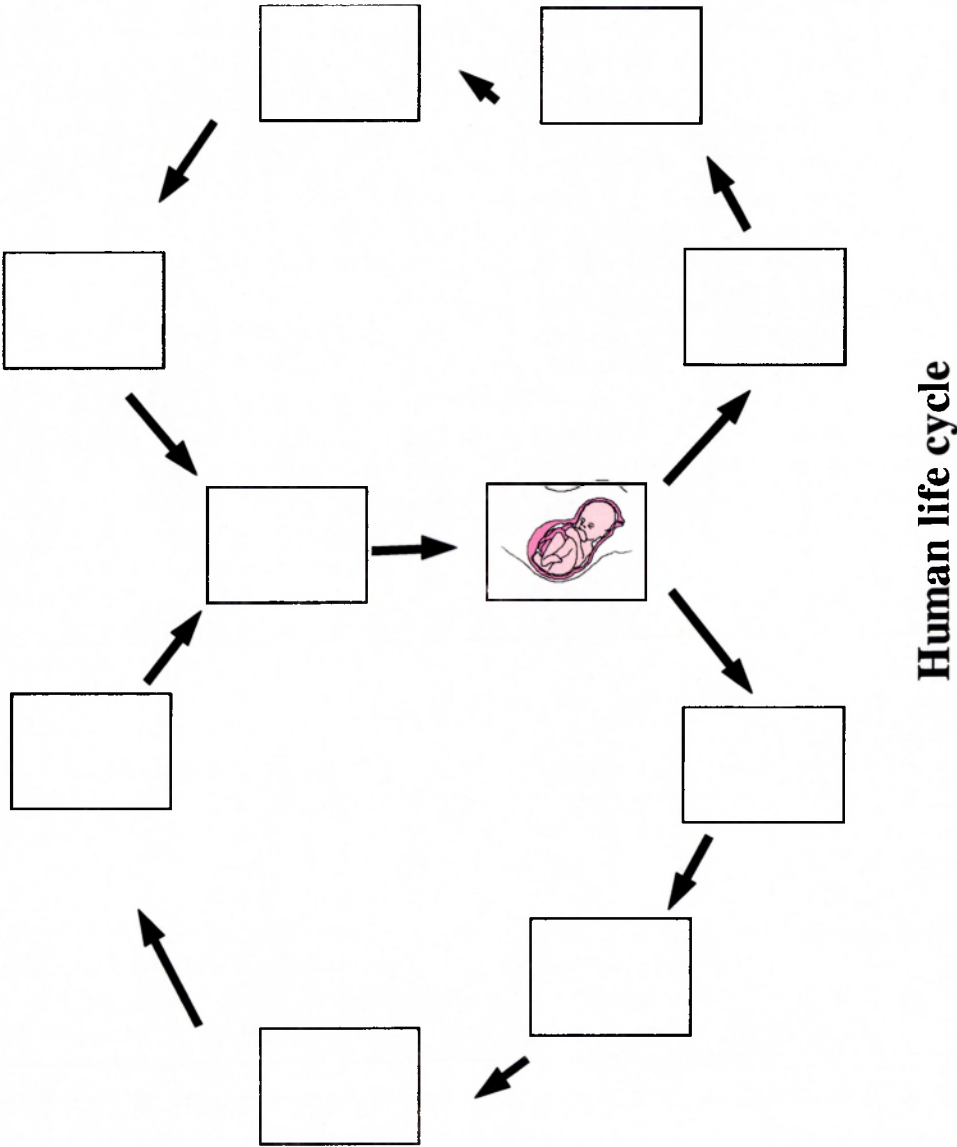
1. Private Meetings with Pupils

- Staff should be aware of the dangers which may arise from private interviews with individual pupils. It is recognised that there will be occasions when confidential interviews must take place. As far as possible, staff should conduct such interviews in a room with visual access, or with the door open.
- Where such conditions cannot apply, staff are advised to ensure that another adult knows that the interview is taking place. It may be necessary to use a sign indicating that the room is in use, but it is not advisable to use signs prohibiting entry to the room.
- Where possible another pupil or (preferably) another adult should be present or nearby during the interview, and the school should take active measures to facilitate this.

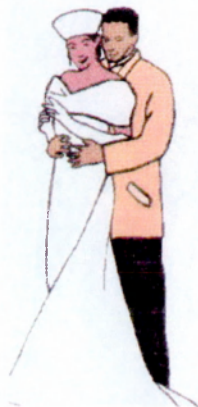
Appendix A.3 (Administration and ethics)
Interview setup



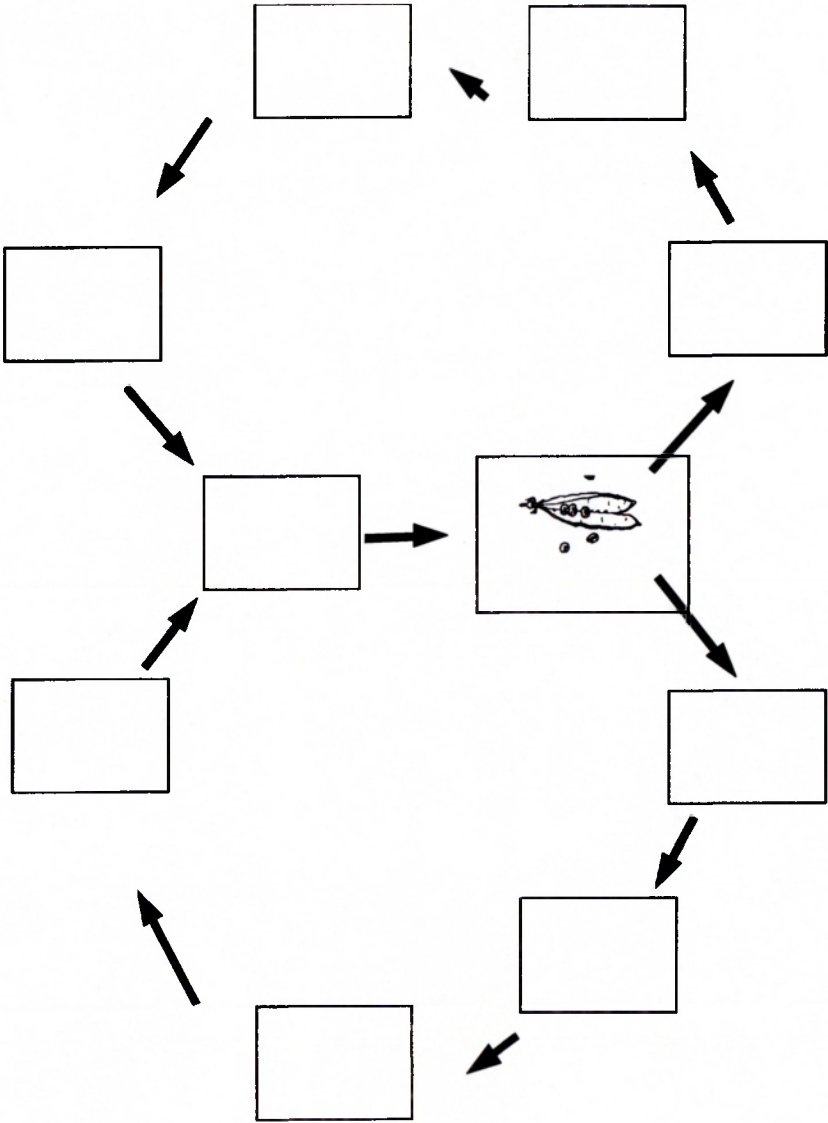
Appendix B.1
Human concept board



Appendix B.2
Human concept cards for laydown on board



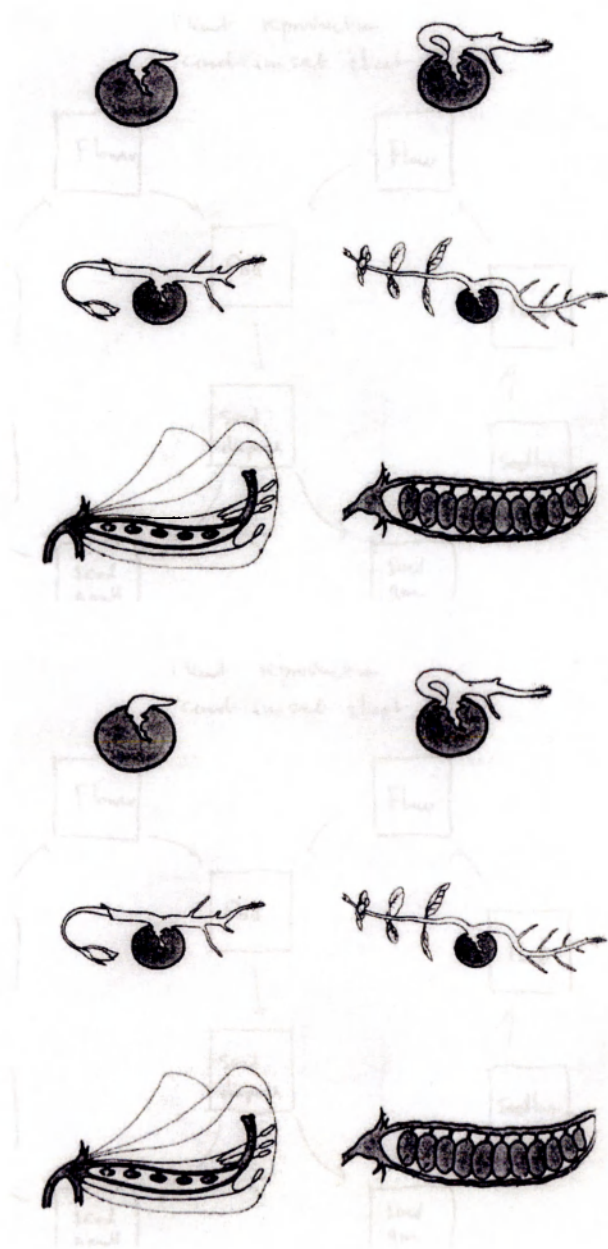
Appendix B.3
Plant concept board



Plant Life Cycle

Appendix B.4

Plant concept cards for laydown on board



Appendix B.5

Sample interview record one

Sample pupil 504

NAME	CLASS	TEACHER	GENDER	HANDED
	5 T	(MAD) OF LMC PT	MAF	LEFT/RIGHT

Time 1m 41sec

Interview schedule

Here is a life cycle board and some cards. You are to sort out the cards in an order that makes a life cycle. The 1st card is done for you.

On completion

Can you tell me, in your own words, the story of the life cycle?

Can you point to the new living thing?

Can you tell me any more about where the new living thing came from or how it was formed?

Further open questions if it appears that the pupil has more to say.

Notes for second set of cards:

1st from Primary School
SHCC

Observation schedule

Plant all correct? ☒ YES

Patterns All correct but Flowers follow path ☒ YES

All Correct? ☒ YES

Mark in mistakes in boxes to right in code shown to left.

Sequencing

Work down pages on page

Work left-right/anti-clockwise

Work clockwise/anticlockwise

Work to form single cycle covering page

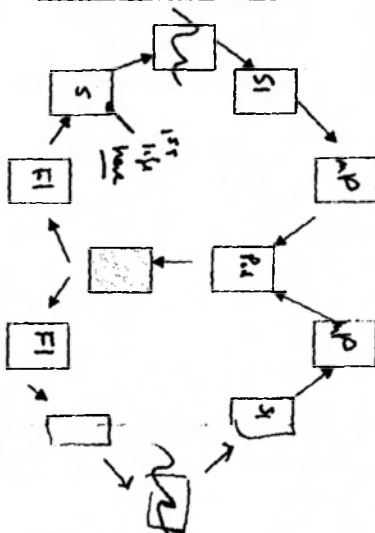
Work to form single cycle half page

Work to form double cycle

Change cycle

Codes	
Seed	s
Seedling	sl
Young plant	yp
Mature plant	mp
Flower	f
pod	p

Plant First/second



Further comments Cards laid down on elastic Ratchet. Tankard had made mistake in attempt at single cycle. Route Route (Tailored by postcard? Cognitive cognitive?) Here can find that movement restructure. Flowers in wrong position

Appendix B.6

Sample interview record two

Sample pupil sat

<p>NAME _____</p> <p>CLASS <u>6T</u></p> <p>TEACHER <u>Ms DP LMC PT</u></p> <p>GENDER <u>Boy</u></p> <p>HANDED <u>Left/Right</u></p>	<p>Observation schedule</p> <p>Human all correct? <u>Y</u></p> <p>Patterns</p> <p>All Correct? <u>Y</u></p> <p>Mark in mistakes in boxes to right in code shown to left.</p> <p>Sequencing</p> <p>Work down page on page</p> <p>Work left-right/Right-left</p> <p>Work clockwise/anticlockwise</p> <p>Work <u>anti-clockwise</u></p> <p>Work to form single cycle covering page</p> <p>Work to form single cycle half page</p> <p>Work to form double cycle</p>
--	---

Time 1m20sec

Interview schedule

Here is a life cycle board and some cards. You are to set out the cards in an order that makes a life cycle. The 1st card is done for you.

On completion

Can you tell me, in your own words, the story of the life cycle?

Can you point to the new living thing?

Can you tell me any more about where the new living thing came from or how it was formed?

Further open questions if it appears that the pupil has more to say.

Repeat for second set of cards.

Knowledge from Primary school same

<p>Codes</p> <p>Baby boy <u>bb</u></p> <p>Teen boy <u>tb</u></p> <p>Young boy <u>yb</u></p> <p>Man <u>m</u></p> <p>Woman <u>w</u></p> <p>Married <u>mar</u></p>	<p>Human First <u>second</u></p>
---	----------------------------------

Quicker, no hesitation about accept for short puns at end (didn't quite work out to sequence?) Complete girl sequence and was unsure about left side. (Single cycle life cycle procedure?) Mixed Baby boy → girl mixed, despite colour coded later.

Appendix B.7

Sample interviews

sample interview subject 'Tanya'

Human 1st

T: tell me the story of the human life cycle

C OK.. the baby is inside the woman., it comes out.... young baby...turns... young girl...turns... Teen boy or girl...adult...married go again (gesticulates at lot, pointing to cards)

T: can you point to where the new life first appears?

C: pointed silently to embryo

T: can you tell me any more about the new life or where it came from?

C: Hesitation (embarrassed) it starts as an egg., in the mothers stomach... and the man ... the father.... (trails off into silence)

T: That's OK. Where did you get your knowledge?

C: Book

T: Just a Book

C Yes

T; What book ? A library book?

C: Yes . A library book

Plant board then completed

T: tell me the story of the Plant life cycle

C: (gesticulates at lot, pointing to cards much more so than in human) Peas come out of the pod... They are planted... watered by rain... roots come out... They grow up to the surface.... making the Petals... Then they come back (pointed to pod)

T: Can you point to where the new life first appears?

C: When you first see it?

C: When you first see it above ground?

T: No. Just first see it.

C: peas to pod

T: Can you tell me any more about the new life or where it came from?

C: it came from inside the fruit... or even a vegetable.

T: Where did you get your knowledge

C: A Book

T: A library Book?

C: No just a book in the house.

#

INITIAL INTERVIEWS

Sample interview two

subject: Steve

plant 1st

T: tell me the story of the human life cycle

Pupil 'Steve' Slowly turns cards over, reflects - adjusts on desk - more reflection - slow lay down pause in air - halt slow descent - final deep thought before decision - incorrect

T: Tell story

A: starts with baby - then toddler - then school - gets older - gets job
Crosses hands and nods vaguely towards board

T: Newlife?

A: gestures to toddler with back of palm. At last moment shifts to neighbouring picture.

T: How new life formed?

A: I don't like to say. Nervous shrug with arms folded

Next sequence Plant

Hesitant selection with rapid laydown, apparently at random. Pace accelerates. Task apparently to finish.

T; Story?

A: Peas - then plant. Folds arms defensively

T: New life?

A: points to mature plant in a loose swing of the arm. At last moment diverts to neighbouring picture

Appendix B.8 First interviews Raw data summary

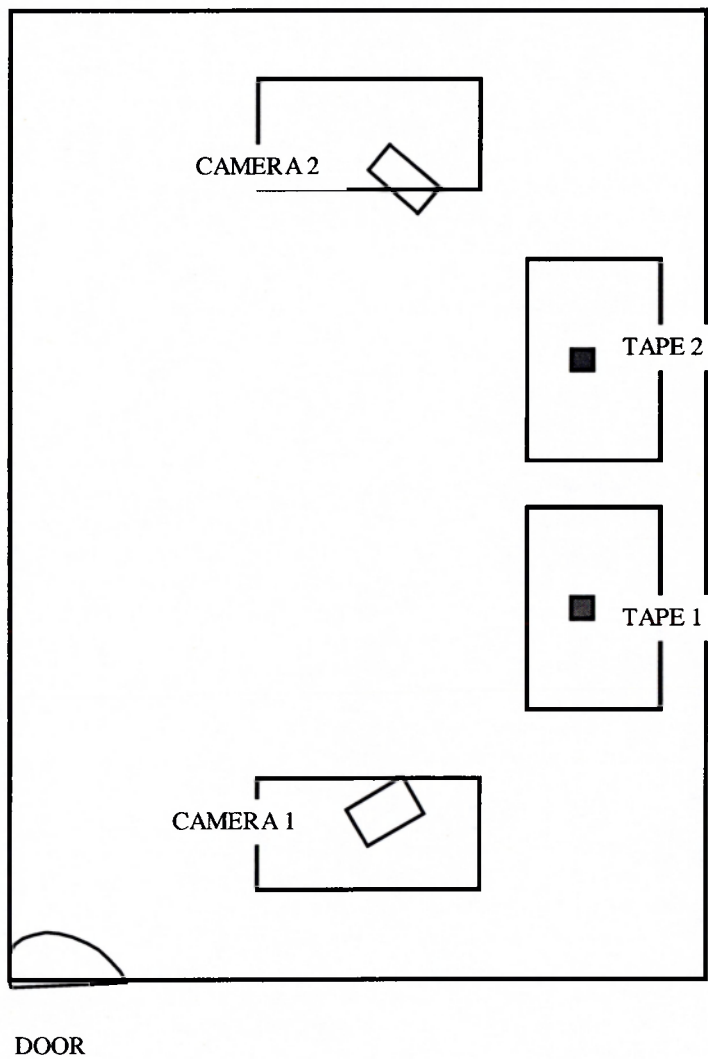
	Human	Human cycle			Plant cycle		seed	
Pupil No.	attempted	completion	correct		Pupil No.	completion	correct	identified
in sequence	first	time (sec)	cycle		in sequence	time (sec)	cycle	correctly
1	*		y		1		y	y
2			y		2		y	y
3	*		y		3		y	y
4	*	181			4	170		y
5		254	y		5	89		y
6	*	101			6	106		y
7		62			7	62	y	y
8		155	y		8	435	y	y
9	*	100			9	152		y
10	*	54			10	50		y
11		85			11	71		y
12		45	y		12	160	y	y
13	*	70	y		13	55	y	y
14	*	64	y		14	102		
15		158			15	102		y
16	*	23	y		16	40	y	y
17		88			17	78		y
18		42			18	37		
19	*	58	y		19	43	y	y
20	*	53	y		20	94		y
21		60	y		21	102		y
22	*	62	y		22	59	y	y
23		51	y		23	176		
24	*	57	y		24	127	y	y
25		36	y		25	53	y	y
26		37	y		26	85	y	y
27	*	53	y		27	41	y	y
28		39	y		28	122		y
29	*	105			29	40		y
30		35	y		30	70		
31	*	48	y		31	60	y	y
32		80			32	101		y
33	*	30	y		33	37	y	y
34		92			34	127		y
35	*	80			35	50		
36		67	y		36	80	y	
37	*	25	y		37	122	y	y
38		53	y		38	75		y
39	*	27	y		39	26	y	y
40		68	y		40	117		y
41		48			41	42		

Appendix B.9 **First interviews** **Raw data summary**

Pupil No.							
in sequence	comment?						
1	initial reflection linked to set-down of cards						
2	asked about dual cycle. Expected single?						
3	Human self-corrected at end. Plant v slow - lots of card replacing						
4	nervous jumbling. Attempt at single cycle using male cards						
5	confusion. Jumble of random movement. "Hunting" movements						
6	Jumble and confusion. Flower and seed not recognised						
7	confusion resolved by action. Rapid movement at random						
8	3 attempts. Early zig-zag hunting movement. Structure deduced?!						
9	laydown, reflection, rearrange. Plant attempted 1 cycle 1st						
10	single cycle dominant						
11	single cycle dominant						
12	single cycle dominant, then correction						
13	initial jumble						
14	confused about plants *						
15	confused single cycle dominant						
16	confused						
17	single cycle dominant						
18	hesitant re-structuring single cycle dominant						
19	decisive, confident, wrong						
20	deliberation and reflection						
21	growing confidence as move to plant						
22	confident						
23	deduction						
24	lay-down, then consolidation						
25	reflection with plant						
26	deliberation and laydown, some surprise at dual cycle						
27	confident						
28	solved plant puzzle - manipulation and deduction.						
29	single cycle human - then confusion.						
30	deliberation manipulation						
31	solved plant puzzle - manipulation and deduction. - growing assurance.						
32	single cycle						
33	confident. Plant reflection.						
34	deduction						
35	both narratives correct						
36	successful deduction						
37	confident and sure						
38	v careful deduction in bptj cases						
39	confident deduction						
40	confusion, single cycle						
41	Finish fast to get out of situation.						

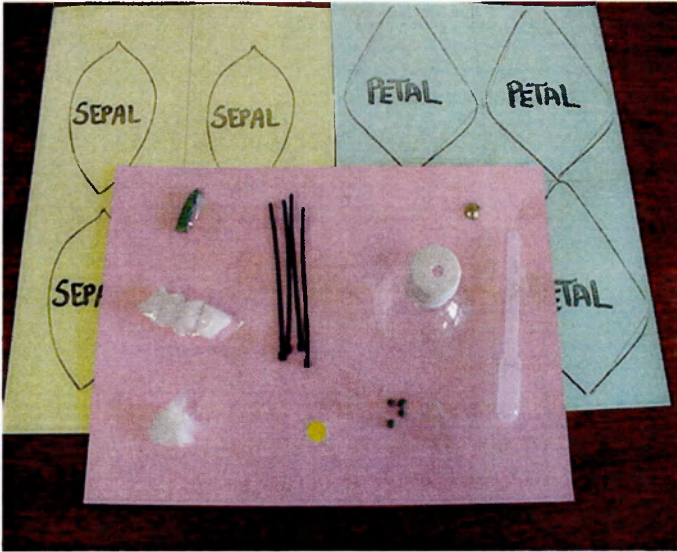
Appendix C.1
Classroom observation setup

CLASS SETUP (A AND B GROUPS ROTATING)



Classroom observation instrument

Model flower kit



Build - a - flower

The Carpel (female bit)

Insert 4 ovules into the ovary. Push in a small piece of cotton wool to keep things in place. Push the style into the top of the ovary. Stick the stigma on top of the style. Rub the top of the stigma with glue - It should be slightly sticky Leave the finished carpel to one side.

The stamen (male bit)

Push the filament into the anther. Put some glue on the anther. Go to the dish in the middle of the room and coat the anther with pollen. Leave the finished stamen to one side

The Flower

Push the carpel into the receptacle. Cut out and stick 4 petals inside the receptacle. Using bits of plasticene, stick the 4 stamens inside the receptacle. Stick 4 sepals to the outside of the receptacle. Using a large marker, write your names on a piece of card and set it beside your completed flower. Ask your teacher to photograph the completed flower.

If you have time draw a cutaway labelled diagram of your flower. Compare it with a diagram in your book. In what ways it is like a real flower? Unlike?

Appendix C.3
flower kit
'mutation'




One group completed the flower early (and incorrectly) and the mutation was copied around the room without hesitation or reflection

Appendix C.4
Classroom observation
'Beetrip'

Group A


1

A Flower
Forms




5

The flower
Withers




3

The bee
Collects pollen




4

The bee
visits another flower




2(3)

A bee
visits the flower



6

A fruit is left behind. Seeds are inside



The pupil was happy with the incorrect sequence until corrected by the teacher. She corrected it by copying from group B2, again without reflection.

Appendix C.5

Classroom observation

Model flower group B1

Bart and Andy

Teacher (T) gives out flower kits and issues instructions about reading the worksheet and following instructions.

Bart (ADHD) imitates Opera singer – Andy admiring

B ‘Can I start Sir?’

T ignores – talks to Girls.

B removes plastic tubes from kit – makes two antlers Andy admiring.
Giggles

B Nose attachments

B blows tubes across desk

B recovers tubes – fangs

T Girls did not read instructions – demand verbal instruction from teacher

B runs fangs across desk. Andy bored, examining work kit

Girls demand further instructuuin

Andy starts work takes carpel from Bart. Bart joins in work for a time.

Class deep concentration for a time during assembly of model flower .

B Carpel as eyelashes

B imitation Quasimodo imitation - Andy and boys irritated.

Other – Bart’s deviant behaviour is accompanied by rapid glances to establish position of teacher. Other pupils initially amused but then annoyed ant not being allowed to go on task.

Appendix C.6

Classroom observation – Brian and Martin

A 3 beetrip

Brian and Martin

T instructions about assembly of Beetrip narrative.

BR bored, plays with audio recorder, accuses M of breaking it, winks at Dave.

M patiently assembles components of cartoon by cutting out

BR ignores him, chats to Roy across desk.

M completes cut-out

BR burst of energy – quick unthinking shuffle – ‘You stick it down’ he tells M

M, unsure, poles at components – quite clearly wrong but he is reluctant to tell BR

BR plays absently with audio recorder, chats to Roy.

Roy anxious about the cartoon assembly, hand up, but can’t get teacher attention

BR overhears teacher advice to Dave. Longer more purposeful period of activity. Discussion with Martin about position of Bees, resolved on basis that BR is the dominant figure.

BR. Back to play – cartoon wrong but settled.

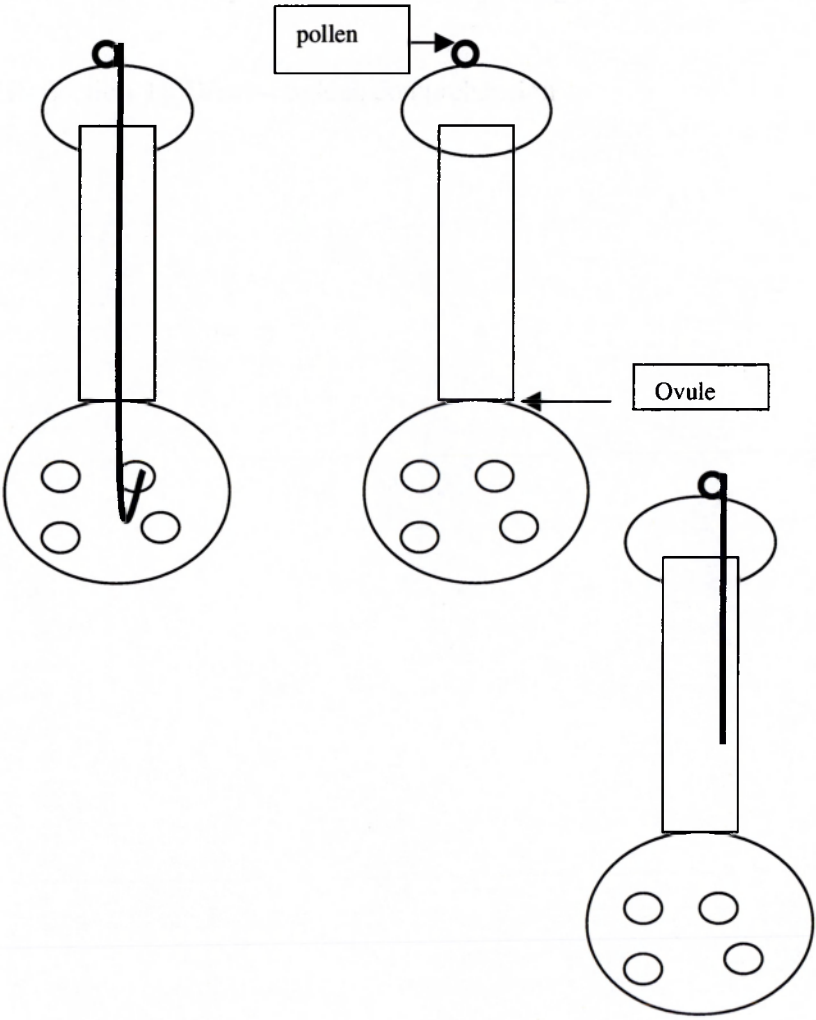
M unsure but lets card slip (without following second 'stick it down' instruction)

T arrives – series of rapid questions What is the cartoon supposed to show? Role of Bees. Why two Bees? Are they doing different things? If so what?

Reflection by Brian – sudden comprehension

Appendix C.7
Classroom observation
Fertilisation

Put the following in the correct sequence and write a sentence about each so as to tell the story of pollination and fertilisation



Appendix D.1

Final interview schedule

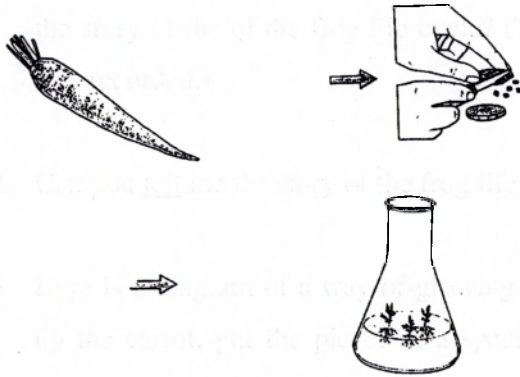
The interview schedule was as follows:

1. Here are cutouts of a frog life cycle. Can you set them down to tell the story of the of the frog life cycle? (The time to set out the cycle was recorded.)
2. Can you tell me the story of the frog life cycle?
3. Here is a diagram of a way of growing carrots indoors). You chop up the carrot, put the pieces in a special jelly and you get lots of small carrots. Scientists call this asexual reproduction. Why is it called reproduction?
4. Why is it called asexual?
5. Here is a cutaway picture of the inside of a flower. Can you point to the male bit?
6. Can you point to the female bit?
7. Now, can you tell me why the male bit is called the male bit?
8. Now, can you tell me why the female bit is called the female bit?

This is a picture of a seed. A few seconds before it was there as you see it, but it wasn't a seed. What has happened to turn it into a seed? (If response is fertilisation, ask what that means).

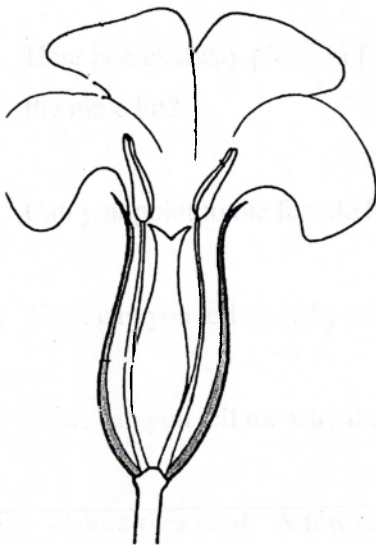
Appendix D.2

Final interview schedule



Here is a diagram of a way of growing carrots indoors). You chop up the carrot, put the pieces in a special jelly and you get lots of small carrots. Scientists call this asexual reproduction. Why is it called reproduction?

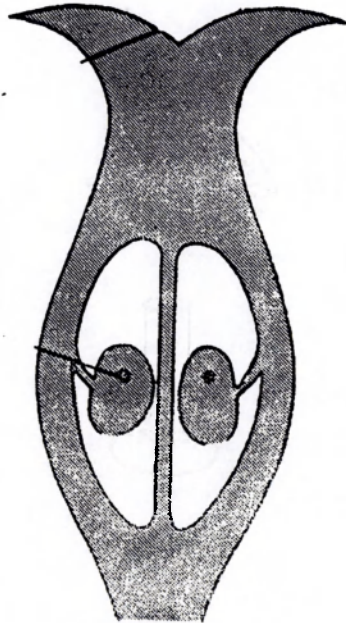
Why is it called asexual?



Here is a cutaway picture of the inside of a flower. Can you point to the male bit?

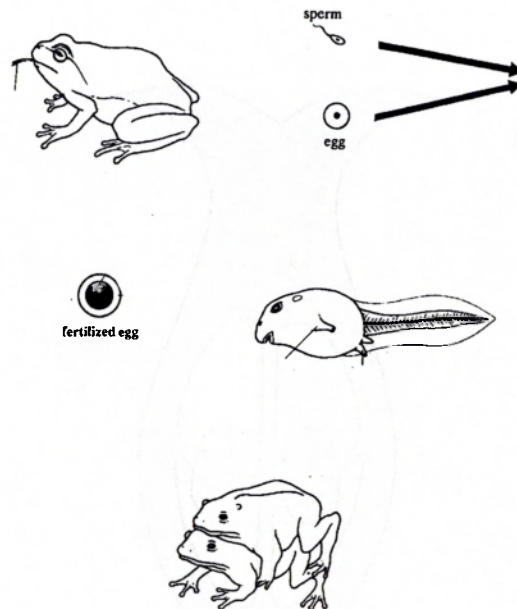
Can you point to the female bit?

Final interview schedule



This is a picture of a seed. A few seconds before it was there as you see it, but it wasn't a seed. What has happened to turn it into a seed? (If response is fertilisation, ask what that means).

Final interview schedule



Here are cutouts of a frog life cycle. Can you set them down to tell the story of the of the frog life cycle? (The time to set out the cycle was recorded.)

Can you tell me the story of the frog life cycle?

Final interviews: raw data summary

ANY= CONCEPT OBSCURED BY HUMAN REPRODUCTIVE CONNOTATION
YELLOW INDICATES FROG LIFE CYCLE FIRST
NN= CONCEPT OBSCURED BY GENERAL IDEAS OF GROWTH

Appendix F.1 School knowledge KS3 curriculum content (NI CCEA)

Reproduction

PLANTS

learn about the structure and functions of the component parts of the flower (limited to a named dicotyledonous plant), including name the parts - sepals, petals, nectaries, stamens, (anthers and filaments), carpels (stigma, style and ovary) and receptacle,

- self and cross-pollination, insects and wind as agents of pollination,
- fruit and seed dispersal - wind, animals, water and explosive mechanisms,
- seed structure - radicle, plumule, cotyledon, testa, endosperm, · seed germination (limited to a hypogeal seed),
- investigate the conditions which affect germination - temperature, adequate water, oxygen supply;

ANIMALS

be introduced to the structure and functions of the component parts of the reproductive systems in humans, including:

naming the parts of the male system - testes, scrotum, sperm ducts, prostate gland, urethra and penis,

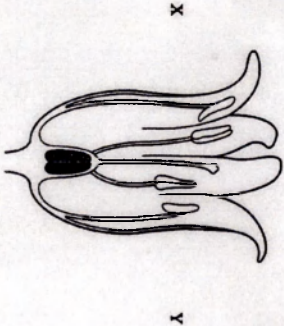
naming the parts of the female system - ovaries, oviducts, uterus, cervix, vagina and vulva,

fertilisation in the oviduct, role of the placenta, birth (limited to contraction of the uterus and dilation of the cervix)

find out about the requirements to maintain healthy bodies and healthy babies during pregnancy, including diet, Rubella, smoking, alcohol, and drugs;

Appendix F.2
School knowledge
NICCEA KS3 sample questions

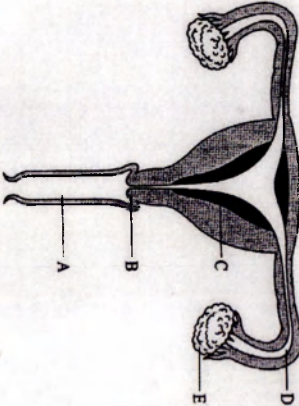
8. The diagram shows a section through a bluebell flower.



- a. i. Draw a line from letter X to a part of the flower where the male reproductive cells are produced. [1]
- ii. Draw a line from letter Y to the part of the flower where fertilisation occurs. [1]
- b. Explain how the nucleus from a pollen grain on the stigma reaches the nucleus of an ovule. [2]

[2]

5. The diagram shows the female reproductive system.



- a. Give the names of parts A, B and D. [3]
- A _____
- B _____
- D _____
- b. Give the letter of the part where each of the following processes takes place:
- i. an ovum is fertilised, _____
- ii. a fertilised ovum is implanted, _____ [2]